CVPIA INSTREAM FLOW INVESTIGATIONS
SACRAMENTO RIVER CHINOOK SPAWNING HYDRAULIC MODELING
KESWICK DAM TO BATTLE CREEK

PREFACE

The following is an interim report for the U. S. Fish and Wildlife Service's investigations on the Sacramento River, part of the Central Valley Project Improvement Act (CVPIA) Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the CVPIA, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U. S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide scientific information to the U. S. Fish and Wildlife Service Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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ACKNOWLEDGMENTS

The field work for this study was conducted by Will Amy, Ed Ballard, Brian Cordone, Mark Gard, John Kelly, Jason Kent, Jeff Thomas and Rick Williams. Data analysis and report preparation were performed by Ed Ballard and Mark Gard. Funding was provided by the Central Valley Project Improvement Act.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring runs), steelhead, and white and green sturgeon. For the Sacramento River, the Central Valley Project Improvement Act Anadromous Restoration Plan calls for October through April flows ranging from 3,250 to 5,500 cfs, with the recommended flow varying with the October 1 carryover storage in Shasta Reservoir (U. S. Fish and Wildlife Service 1995). In December 1994, the U. S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Sacramento River. The purpose of this report is to produce models predicting the hydraulic and structural characteristics of spawning sites for chinook salmon in the Sacramento River between Keswick Reservoir and Battle Creek over a range of streamflows. The Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM) was used for this modeling. The results of this study are intended to support or revise the flow recommendations above.

METHODS

Study Site Selection

We have divided the Sacramento River study area into six stream segments, based on hydrology and other factors: Grimes to Colusa (Segment 1); Deer Creek to Red Bluff Diversion Dam (Segment 2); above Lake Red Bluff to Battle Creek (Segment 3); Battle Creek to Cow Creek (Segment 4); Cow Creek to ACID (Segment 5); and ACID to Keswick (Segment 6). Segment 1 addresses green and white sturgeon, while the other segments address chinook salmon.

Aerial redd survey data for 1989-1994 collected by Frank Fisher (CDFG) for each of the four runs of chinook salmon were analyzed to determine the most heavily used spawning mesohabitat units (primarily riffles). Insufficient data were available for spring-run chinook salmon. This race is thought to be primarily a tributary spawner and it has proven impossible to differentiate those that do spawn in the mainstem from fall-run adults present at the same time. For the other three races, the mesohabitat units were ranked in each of the stream segments, to identify those areas which consistently received the heaviest spawning use. Segment 6 appears to be important primarily for late fall-run spawning, with 24% of the late fall redds in this segment. Segments 5 and 4 are important for all three races with, respectively, 35% and 12% of fall-run spawners, 51% and 8% of late fall spawners, and 80% and 3% of winter-run spawners. An updated analysis of fall-run spawning distribution, using CDFG aerial redd survey data for 1989-1998, found a similar distribution, with 36% and 9% of fall-run redds in, respectively, Segments 5 and 4.

In March and April, 1997 we conducted a reconnaissance of the mesohabitat units in Table 1 to determine their viability as study sites. Each potential study site was evaluated based on morphological and channel characteristics which facilitate the development of reliable hydraulic models. Also noted were riverbank and floodplain characteristics (e.g. steep, heavily vegetated berms or gradually sloping cobble benches) which might affect our ability to collect the necessary data to build these models. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

Table 1
Top-ranked Mesohabitat Units for Chinook Salmon Spawning
Based on Aerial Redd Survey Data

Stream Segment	River Mile	Location	Races[1]
6	298.7-298.8	Lower Lake Redding Site	LF
6	299-299.3	Upper Lake Redding Site	LF
6	300.6	Salt Creek Site	LF
6	299.9	Island Site	LF
5	296.3-296.4	299 Bridge Riffle Site	F, LF, W
5	287.6-287.7	Knighton Riffle Site	F
5	297.2	Turtle Bay Side Channel Site	F, LF
5	297.7-298	Posse Grounds Site	F, LF, W
5	282.7-282.8	Above Hawes Hole Site	F, LF
5	298.4	Bridge Riffle Site	F, LF, W
5	291.8	Tobiasson Riffle Site	W, (F, LF)
5	296.6-296.8	Palisades Site	W
5	293.2	Canyon Creek Site	W
4	279.2	Powerline Riffle Site	F, LF, W
4	277.5	Bear Creek Site	F
4	276.1	Balls Ferry Riffle Site	F, LF
4	271.5-271.7	Price Riffle Site	F, LF, W
4	273.4-273	Cottonwood Riffle Site	F, LF, W
4	279.7	Below Cow Creek Site	LF

[1] F = fall-run, LF = late fall-run, W = winter-run. Races in parentheses were not ranked among the highest for that stream segment, but are included because they used the mesohabitat unit relatively heavily and the mesohabitat unit was ranked high for another race.

After reviewing the field reconnaissance notes and considering time and manpower constraints, eight study sites were selected for modeling: 1) Salt Creek; 2) Upper Lake Redding; 3) Lower Lake Redding; 4) Bridge Riffle; 5) Posse Grounds; 6) Above Hawes Hole; 7) Powerline Riffle; and 8) Price Riffle. The first three of these are in Segment 6 and are used by spawning late fall-run salmon. Sites four and five are located in Segment 5 and are used by all three chinook races; site six is also in Segment 5 and used by fall- and late-fall run salmon. Sites seven and eight are used for spawning by all three races and are located in Segment 4. The river mile location of each of these sites is found in Table 1.

In Segment 6 the Island Site was bypassed due to its low ranking and the inclusion of the other three sites in the segment. In Segment 5, the Turtle Bay Side Channel and Highway 299 Bridge Riffle sites were eliminated because changes in the channel morphology had occurred in two successive years and it was feared that any data collected at these sites would not remain valid. The Palisades and Tobiasson Riffle sites were not included due to hydraulic complexities (i.e., transverse and reverse flow patterns) which would be impossible to model effectively with the single dimension hydraulic models within PHABSIM[2]. Knighton Riffle was not selected because of potentially insurmountable logistical problems with surveying the site to obtain bed and water surface elevations. Finally, the Canyon Creek site was not selected due to its low ranking and because three more heavily used spawning areas had already been selected in the segment. In Segment 4, the Balls Ferry Site was eliminated due to the presence of heavily vegetated levees on both riverbanks which exceeded heights of 20-25 feet. The sites below Cow Creek and at Cottonwood Riffle were not included due to their low ranking and because two more heavily used spawning areas had already been selected in the segment. The Bear Creek site was not selected because it was only heavily used by fall-run salmon.

Transect Placement (study site setup)

A total of 34 transects were placed in the established study sites. At each site, transects were located to cross the areas most heavily used by spawning chinook salmon (as identified by Kurt Brown, Red Bluff FWS and on CDFG aerial photographs). Transect pins (headpins and tailpins) were marked on each river bank above the 15,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. The study sites, reach number, and number of transects placed at each site are shown in Table 2.

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[2] PHABSIM is the Physical Habitat Simulation component of the IFIM. It is the collection of hydraulic and habitat models which are used to predict the relationship between physical habitat availability and streamflow over a range of river discharges.

Table 2
Sacramento River Chinook Spawning Sites

Site Name	Reach Number	Number of Transects
Salt Creek	6	1
Upper Lake Redding	6	2
Lower Lake Redding	6	1
Bridge Riffle	5	3
Posse Grounds	5	10
Above Hawes Hole	5	6
Powerline Riffle	4	6
Price Riffle	4	5

Hydraulic and Structural Data Collection

Benchmarks were established at each site to serve as the reference elevation to which all elevations (streambed and water surface) were tied. The benchmarks for all of the sites above ACID were tied together to provide the option of using the *WSP* hydraulic model to simulate water surface elevations all the way from the ACID Dam to the Salt Creek site. The data collected on each transect included: 1) water surface elevations (WSELs), measured to the nearest .01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate classification at these same locations and also where dry ground elevations were surveyed. Hydraulic and structural data collection began in May 1997 and was completed in March 1999.

Water surface elevations were measured at all sites at the following flow ranges: 4,000-5,000 cfs, 7,500-10,500 cfs, 13,500-15,500 cfs, and 29,000-41,000 cfs. Water surface elevations were also collected at a range of 6,000-7,000 cfs (Price Riffle, Lower Lake Redding, Upper Lake Redding, and Salt Creek), and 25,000-26,000 cfs (Posse Grounds and Above Hawes Hole). Depth and velocity measurements were collected at all sites for the flow range of 13,500-15,500 cfs, with the exception of Above Hawes Hole and Posse Grounds transects one through eight. Depth and velocity measurements at Above Hawes Hole and Posse Grounds transects one through eight were made at a flow range of 7,500-10,500 cfs. Edge-cell water velocities were collected along the left bank on June 9 and August 10, 1998 at a flow of around 14,000 cfs for Posse Grounds transects one through eight because water velocities collected at a flow of around 8,000 cfs were not representative of conditions at higher flows.

Depth and velocity measurements in portions of the transects with depths greater than three feet were made with the Broad-Band Acoustic Doppler Current Profiler (ADCP), while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney[R] model 2000 or a Price AA velocity meter. Starting at the water's edge, water depths and velocities were made at measured intervals using the wading rod and Marsh-McBirney[R] model 2000 or Price AA velocity meter until the water became sufficiently deep to operate the ADCP (approximately 3 feet). The distance intervals of each depth and velocity measurement from the headpin or tailpin were measured using a hand held laser range finder[3]. At the location of the last depth and velocity measurement made while wading, a buoy was placed to serve as a starting point for the ADCP. The boat was then positioned so that the ADCP started operation at the buoy, and water depth and velocity data were collected across the transect up to the location near the opposite bank where water depths of approximately 3 feet were reached. A buoy was placed at the location where ADCP operation ceased and the procedure used for measuring depths and velocities in shallow water was repeated until the far bank water's edge was reached.

Substrate classification was accomplished using underwater video equipment along the deepwater portion of the transects and visually in shallow water. The underwater video equipment consists of two waterproof remote cameras mounted on an aluminum frame with two 30-lbs. bombs. One camera is mounted at a 45° angle and the second camera is mounted at a 90° angle. The camera mounted at a 45° angle was used for distinguishing changes in substrate size classes, while the camera mounted at 90° was used for assessing substrate size. The frame is attached to a cable/winch assembly, while a separate cable from the remote cameras is connected to two TV monitors on the boat. The two monitors are used by the winch operator to distinguish changes in substrate size classes and determine the substrate size. Substrates were visually assessed (using a calibrated grid[4] on the monitor connected to the 90° camera for the deep water substrates) for the dominant particle size range (e.g., range of 2-4"). Table 3 gives the substrate codes and size classes used in this study. The substrate sizes were visually assessed from the

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[3] The stations for the dry ground elevation measurements were also measured using the hand held laser range finder.

[4] The grid was calibrated so that, when the camera frame was one foot off the bottom, the smallest grid corresponded to a two-inch substrate, the next largest grid corresponded to a four-inch substrate, etc.

Table 3
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium/Large Gravel	1 - 3
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Small Cobble	3 - 4
3.5	Small Cobble	3 - 5
4.6	Medium Cobble	4 - 6
6.8	Large Cobble	6 - 8
8	Large Cobble	8 - 12
9	Boulder/Bedrock	> 12

headpin or tailpin to the location along the transect where the water became too deep for further visual assessment. At each change in substrate size class, the distance from the headpin or tailpin was measured using a hand held laser range finder. A buoy was placed at the location where visual assessment stopped and assessment from that point was continued across the transect by boat using the video camera assembly, with the distances where substrate size changed again measured with the hand held laser range finder. A buoy was again dropped at the location along the transect near the opposite shore where shallow water depth prevented further progress by boat. The substrate over the remaining distance from the buoy to the end of the transect was assessed using the same visual methods used on the opposite bank.

All data were compiled and checked before entry into PHABSIM data decks. ASCII files of each ADCP run were produced using the Playback feature of the Transect program[5]. Each ASCII file was then imported into RHABSIM Version 2.0 to produce the bed elevations, average water column velocities, and stations (relative to the start of the ADCP run). RHABSIM was then used to output a second ASCII file containing this data. The second ASCII file was input into a QuattroPro spreadsheet and combined with the velocity, depth, and station data collected in shallow water. Typically, the last wet cell in shallow water had a measured velocity of 0 ft/s. These velocities were arbitrarily set to a low value (typically 0.01 ft/s) to get reasonable simulated velocities in cells that were dry at the velocity measurement flow. This practice is judged to be reasonable, since the measurement error of velocities is in the range of 0.01 ft/s. We defined a statistic (R) to provide a quality control check of the velocity measured by the ADCP at a given station n, where $R = Vel_n/(Vel_{n-1} + Vel_{n+1})/2$ at station n[6]. R was calculated for each velocity where Vel_n, Vel_{n-1} and Vel_{n+1} were all greater than 1 ft/s for each ADCP data set. Based on data collected using a Price AA velocity meter on the Lower American River, the acceptable range of R was set at 0.5-1.6. All verticals with R values less than 0.5 or greater than 1.6 were deleted from each ADCP data set. Flows were calculated for each ADCP run, including the data collected in shallow water. The run for each cross section which had the flow closest to the actual flow, determined from gage readings[7] (Table 4), was selected for use in the PHABSIM decks. The ADCP runs selected for use are shown in Table 5 and the ADCP settings used for the ADCP runs selected for use are shown in Table 6.

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[5] The Transect program is the software used to receive, record and process data from the ADCP.

[6] n - 1 refers to the station immediately before station n and n + 1 refers to the station immediately after station n.

[7] As shown in Table 4, the flow calculated at Bend Bridge from upstream and tributary gage readings often differed from the gage reading at Bend Bridge by less than 5% and never differed by more than 10.5%. Similarly, as shown in Table 5, the measured discharge usually differed from the flow calculated from gage readings by less than 5% and never differed by more than 11%. Flows could be calculated using either USBR or USGS flows measured at Keswick Dam; the flows selected for use were those which had the smaller Bend error.

Table 4
Study Site Flows (cfs)

Date	Salt Creek	Upper & Lower Lake Redding	Bridge & Posse	Hawes Hole	Powerline	Price	Bend err	Keswick Flow Used
5/19/97	9513	9483					4.70%	USBR
5/20/97			9228				5.25%	USBR
6/04/97				10226			4.80%	USGS
6/05/97					10354		2.85%	USBR
6/24/97	14600	14570					1.95%	USGS
6/25/97			14483				2.40%	USGS
6/26/97			14618	14620			0.36%	USGS
7/08/97					14628		0.29%	USGS
7/09/97					14818		1.82%	USGS
7/10/97						14936	2.41%	USGS
7/22/97	15400	15370	15178				0.82%	USGS
7/23/97					15097		3.55%	USGS
7/29/97						14371	0.51%	USBR
7/30/97						14389	1.70%	USGS
8/25/97						8953	3.69%	USGS
8/26/97				8320			6.80%	USGS
8/27/97				8293			5.12%	USBR
8/28/97			7847				7.96%	USBR
9/9/97			8454				4.30%	USGS
9/10/97			8396				3.13%	USGS
9/11/97			7661				7.59%	USBR
9/23/97						6844	5.45%	USGS
10/07/97					4952		8.90%	USBR
10/15/97						4819	9.77%	USBR

Table 4 (Continued)

Date	Salt Creek	Upper & Lower Lake Redding	Bridge & Posse	Hawes Hole	Powerline	Price	Bend err	Keswick Flow Used
10/16/97				4542			10.38%	USBR
11/05/97			4662				3.50%	USBR
1/21/98	29855	29825	29855				4.49%	USBR
1/22/98			35059	36589	38769	42112	1.36%	USBR
6/09/98			13915				1.76%	USGS
9/04/98		13570					2.28%	USGS
10/13/98	6580	6550					7.47%	USGS
11/19/98	14900	14870					1.48%	USGS
12/08/98				26106			1.42%	USGS
2/16/99				25100			6.12%	USBR
3/16/99			14500				6.18%	USGS

A table of substrate ranges/values was created to determine the substrate for each vertical/cell (e.g, if the substrate size class was 2-4" on a transect from station 50 to 70, all of the verticals with station values between 50 and 70 were given a substrate coding of 2.4). Dry bed elevation data in field notebooks were entered into the spreadsheet to extend the bed profile up the banks above the WSEL of the highest flow to be modeled. An ASCII file produced from the spreadsheet was run through the FLOMANN program (written by Andy Hamilton) to get the PHABSIM input file and then translated into RHABSIM files. RHABSIM was used rather than PHABSIM because the number of verticals per transect exceeded 100.

All of the measured WSELs were checked to make sure that water was not flowing uphill. Those WSELs that showed water flowing uphill were modified before being used in the decks[8]. A total of three to five sets of WSELs at widely spaced flows were used; if WSELs were available for several closely spaced flows, the WSEL that corresponded with the velocity set was used in the decks.

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[8] The only WSELs that showed water running uphill were those measured at two flows at the Upper Lake Redding site. For these flows, the WSEL at transect 1 was 0.02 to 0.07 feet higher than the WSEL at transect 2. We attribute this to small errors in measurements of WSELs and in tying together the benchmarks for the Upper Lake Redding site. For these flows, we set the WSEL for transect 2 equal to the WSEL at transect 1. These measurements were all taken when the ACID boards were in, and there was an extremely flat water surface elevation gradient in the site.

Table 5
ADCP Files Used for Velocity Sets

Site Name	XS Number	File Name	Measured Q	% Difference
Salt Creek	1	D85D001	14228	3%
Upper Lake Redding	1	D45D005	15109	4%
Upper Lake Redding	2	D45D009	15293	5%
Lower Lake Redding	1	D45D011	15144	4%
Bridge Riffle	1	S45D005	15402	6%
Bridge Riffle	2	MD4C010	15461	2%
Bridge Riffle	3	MD4C006	15123	1.7%
Posse Grounds	1	MD4C064	6642	1%
Posse Grounds	2	MD4C062	7657	7%
Posse Grounds	3	MD4C059	7382	5%
Posse Grounds	4	MD4C057	7193	4%
Posse Grounds	5	MD4C054 (RC), MD8A004 (LC)	8903	5.7%
Posse Grounds	6	MD4C056 (RC), MD8A005 (LC)	8567	2%
Posse Grounds	7	MD4C046 (RC), MD4A033 (LC)	8133	4%
Posse Grounds	8	MD4A027 (RC), MD4A030 (LC)	8563	3.6%
Posse Grounds	9	S45D012	15552	7%
Posse Grounds	10	D45D017	15645	7.26%
Above Hawes Hole	1	MD4C043	8504	3%
Above Hawes Hole	2	MD4C041	9221	11%
Above Hawes Hole	3	MD4C039	7830	6%

Table 5 (continued)

Site Name	XS Number	File Name	Measured Q	% Difference
Above Hawes Hole	4	MD4C037	8799	6%
Above Hawes Hole	5	S45D022	8179	2%
Above Hawes Hole	6	MD8A003	8348	0%
Powerline Riffle	1	S85D008	15672	4%
Powerline Riffle	2	S85D009	15893	5%
Powerline Riffle	3	S45D019	15543	6.3%
Powerline Riffle	4	S45D016	15109	3%
Powerline Riffle	5	S45D015	15134	3%
Powerline Riffle	6	S85D003	14993	2%
Price Riffle	1	MD4C020	14599	1.6%
Price Riffle	2	MD4CO22	14697	2%
Price Riffle	3	MD4C024	13623	1%
Price Riffle	4 (MC)	MD4CO26	13728	1%
Price Riffle	4 (SC)	MD4C030	479	5%
Price Riffle	5 (MC)	MD4A018	14340	3%

The WSELs used in the decks, along with the distances between transects, were then used to compute the slope to be used for each transect, as follows. For each transect, two slopes were computed at each measured flow, one using the difference in WSELs between the transect and the next transect downstream divided by the distance between the two, and the other in the same fashion using the next transect upstream. Each of these two slopes were averaged for all measured flows, and these two averages were then averaged again to determine the final slope used in the velocity simulation. For transects at either end of a study site (where either an adjacent upstream or downstream transect was absent), slopes were calculated minus the final averaging step. For the Lower Lake Redding site, the slope was calculated using WSELs measured at the transect and at the ACID Dam. For the Salt Creek site, the slope was calculated using a WSEL measured at the transect, and a WSEL measured at a given distance upstream of the transect.

Table 6
CFG Files[9] Used for ADCP Data used in PHABSIM Decks

CFG File	Mode	Depth Cell Size (cm)	Depth Cell Number	Max Bottom Track (ft)	Pings	WT	First Depth Cell (ft)	Blanking Dist. (cm)
MD8A	8	20	15	26	4	5	1.61	10
S45D	8	20	15	26	4	5	1.94	20
S85D	8	20	15	26	8	5	1.94	20
MD4C	4	10	30	26	4	5	1.51	10
MD4A	4	20	15	26	8	5	1.84	10
D45D	8	20	30	26	4	5	1.94	20
D85D	8	20	30	26	8	5	1.94	20

A separate deck was constructed for each study site. In addition, a separate deck was constructed for each split channel for each transect for Posse Grounds transects one through eight and for the main and side channel for Price transects three through five. For the sites above ACID, separate decks were constructed for two conditions: 1) with the ACID Dam boards in; and 2) with the ACID Dam boards out.

The stage of zero flow (SZF), an important parameter used in calibrating the stage-discharge relationship, was determined for each transect and entered. In habitat types without backwater effects (e.g., riffles and runs), this value generally represents the lowest point in the streambed across a transect. However, if a transect directly upstream contains a lower bed elevation than the adjacent downstream transect, the SZF for the downstream transect applies to both. For all of the sites above ACID, the SZF ended up being the low point on the ACID Dam; with the boards out, it was the dam elevation and with the boards in, it was the right bank fish ladder exit elevation.

Calibration flows in the data decks (Appendix B) were the flows calculated from gage readings. Linear regression was used to develop relationships between the streamflow in the Price transects three through five side channels and the total river flow. Linear regression was also used to develop relationships between the streamflow in each split channel of Posse Grounds transects one through eight and the total river flow, using as independent variables the total river flow and the distance above transect one. These regression equations were used to estimate streamflow in

[9] The first four characters of the ADCP runs designates which CDG file (containing the ADCP settings) was used for the runs.

each split channel of Posse Grounds transects one through eight and in the main and side channel for Price transects three through five for each of the simulated total river flows, and to determine the flows to use for calibration.

The first step in the calibration procedure was to determine the best approach for WSEL simulation. Initially, the *IFG4* hydraulic model (Milhous *et al.*, 1989) was run on each deck to compare predicted and measured WSELs. This model produces a stage-discharge relationship using a log-log linear rating curve calculated from at least three sets of measurements taken at different flows. Besides *IFG4*, two other hydraulic models are available in PHABSIM to predict stage-discharge relationships. These models are: 1) *MANSQ*, which operates under the assumption that the condition of the channel and the nature of the streambed controls WSELs; and 2) *WSP*, the water surface profile model, which calculates the energy loss between transects to determine WSELs. *MANSQ*, like *IFG4*, evaluates each transect independently. *WSP* must, by nature, link at least two adjacent transects. *IFG4,* the most versatile of these models, is considered to have worked well if the following standards are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot difference between measured and simulated WSELs. For a majority of the transects for at least a portion of the measured flows, *IFG4* met the above standards (Appendix B). *MANSQ* worked successfully for a number of transects, meeting the latter three above standards (Appendix B)[10]. *WSP* worked successfully for the remaining transects, with the last standard being met[11].

For most of the transects, we needed to simulate low and high flows with different sets of calibration WSELs (Appendix B) to meet the above standards. For transects where we had measured five sets of WSELs, *IFG4* could be run for low flows using the three lowest calibration WSELs, and run for high flows using the three highest calibration WSELs. For transects where we had only measured four sets of WSELs, we typically used *IFG4* with the three highest or three lowest flows to simulate, respectively, the high or low flows, and used *MANSQ* or *WSP* with the two lowest or two highest flows to simulate the remaining flows.

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[10] The first standard is not applicable to *MANSQ*, although having the beta value parameter used by *MANSQ* within the range of 0 to 0.5 (as was the case for all transects calibrated with *MANSQ*, as shown in Appendix B), is an analogous standard for *MANSQ*.

[11] The other standards are not applicable to *WSP*. However, for all transects calibrated with *WSP* except Upper Lake Redding, the Manning's n value used fell within the acceptable range (0.04 - 0.07), and there was a negative log-log relationship between the reach multiplier and flow (another indication of acceptable *WSP* calibration). We feel justified in using a manning's n value of 0.02 and a positive log-log relationship between the reach multiplier and flow for the Upper Lake Redding site with the boards in at ACID because there is such a strong backwater effect from the dam with the boards in. Also, the average manning's n calculated for these transects from depth, velocity and slope data was 0.02.

Simulation of WSELs for the sites above ACID with the ACID Dam boards in posed a unique problem. Operations of the ACID Dam involves adjustments in the number of boards placed in the dam. Since the boards are 0.5 feet high, we were able to adjust the WSELs that we measured at the ACID Dam by adding or subtracting multiples of 0.5 feet, based on the number of boards that were in the dam on the date that we measured the WSEL; the WSELs were adjusted so that they all corresponded to the same number of boards in the ACID Dam[12]. Our original plan was to use *WSP* to simulate WSELs at all of the sites above ACID, using WSELs at the ACID Dam as an input to *WSP*. However, *WSP* did not work to simulate WSELs at the Lower Lake Redding transect. Our only remaining option for the Lower Lake Redding transect was to use the same adjustments of WSELs that we used for the ACID Dam. Since the change in WSEL at the Lower Lake Redding site with changes in the number of boards in the ACID Dam is also affected by the channel between the ACID Dam and the Lower Lake Redding transect, this adjustment resulted in measured versus predicted WSELs that differed by up to 0.16 foot. Even though this does not meet the last standard for *IFG4*, we still used this method to simulate WSELs at the Lower Lake Redding transect, since *WSP* and *MANSQ* produced much greater errors in simulated WSELs. We were able to use *WSP* to simulate WSELs at the Upper Lake Redding transects, using the Lower Lake Redding WSELs as an input to *WSP*, as follows: 1) the measured WSELs at Lower Lake Redding and Upper Lake Redding were used to determine the relationship between reach multiplier and flow; and 2) the reach multiplier-flow relationship was used with the adjusted WSELs from the Lower Lake Redding site to simulate WSELs at the Upper Lake Redding site for a fixed number of boards in the ACID Dam[13]. We found that *IFG4* worked using the measured WSELs at Salt Creek; apparently, the number of boards in the ACID Dam does not have a significant effect on the WSELs at Salt Creek.

The last standard for *IFG4* was not met at only one other transect (Price Transect 2 for high flows). As for the Lower Lake Redding site, we still used *IFG4* for this transect because *MANSQ* and *WSP* gave much greater errors in WSELs than *IFG4*. While the middle two standards were met for all transects where we used *IFG4*, the beta coefficient values were less than 2.0 for the following transects/flows: 1) Salt Creek boards in; 2) Lower Lake Redding boards in and out; 3) Hawes transects two through four for high flows; 4) Powerline transects one through six for high flows; and 5) Price transect two. In addition, the Velocity Adjustment Factors (VAF) for Powerline transects one through five (Appendix C) decreased with increasing flow at high flows. VAFs typically increase monotonically with increasing flows as higher flows produce higher water velocities. The model, in mass balancing, was obviously decreasing water velocities at high flows so that the known discharge would pass through the increased cross-sectional area. We

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[12] For example, if there was one more set of boards in the ACID Dam, we subtracted 0.5 feet from the measured WSEL. This adjustment assumes that the change in WSEL will be the same as the change in the elevation of the top of the boards in the ACID Dam.

[13] This method assumes that the reach multiplier-flow relationship is independent of the number of boards in the ACID Dam.

concluded that both of these phenomena were caused by channel characteristics which form hydraulic controls at some flows but not at others (compound controls), thus affecting upstream water elevations. Specifically, at lower flows the channel at these transects controlled the water surface elevations, while at higher flows the water surface elevations were controlled by downstream hydraulic controls[14]. Accordingly, the performance of *IFG4* for these transects was considered adequate despite the beta coefficient standard not being met.

The final step in simulating WSELs was to check whether water was going uphill at any of the simulated WSELs. This occurred at the lowest simulated flows for Posse Grounds transect 9, and at the highest simulated flows for the Lower Lake Redding transect with ACID Dam boards in, for the left channel of Posse Grounds transect three and for the right channel of Posse Grounds transect four. It appears that there is a very low WSEL gradient at these transects and flow ranges; accordingly, we used *WSP* for these transects by setting the simulated WSELs for the transect equal to the WSEL at the next-most downstream transect for the Posse Grounds transects or ACID Dam for the Lower Lake Redding transect.

Velocity calibration is the final step in the preparation of the hydraulic models for use in habitat simulation. The first step in velocity calibration was to calculate Manning's n values for the left-bank edge cells at Posse Grounds transects one through eight, for all of the cells in the sites above ACID, and for edge cells at Price transect 4 side channel. Manning's n is calculated using the following formula:

$$n = 1.486\,(S^{.5})(d^{.667})/V,$$

where S = slope, d = depth and V = velocity. When Manning's n values are written in cells of a PHABSIM data deck, *IFG4* uses the Manning's n values to calculate the velocity for those cells at each simulated flow. For the Posse Grounds transects, Manning's n values were calculated using the depths and velocities measured at 14,000 cfs; these Manning's n values were written into data decks used to simulate flows greater than 7,500 to 8,500 cfs, while they were not written into data decks used to simulate flows less than 7,500 to 8,500 cfs[15]. For the sites above ACID, Manning's n values were calculated from the depths and velocities measured at the velocity set flow; Manning's n values were written into these decks to be able to simulate velocities with both the ACID dam boards in and out based on velocity sets measured only with the ACID dam boards in. For the Price transect four side channel, Manning's n values were

[14] The applicable control for the sites above ACID was the ACID Dam; the hydraulic control for the Hawes and Powerline sites were transverse bars located below the sites; the hydraulic control for Price transect two was Price transect one (note that the beta value for Price transect one was greater than 2).

[15] For these decks, *IFG4* would use the velocities measured at the velocity set flow to simulate velocities at the modeled flows.

calculated using depths and velocities measured at 8953 cfs for the cells that were dry at 6844 cfs. The deck for this transect has Manning's n values written into the above cells, and velocities measured at 6844 cfs for the remaining cells that were wet at 8953 cfs. This procedure was used because of poor data quality of the velocities collected at 8953 cfs (with the ADCP) in the cells that were wet at 6844 cfs.

An *IFG4* input deck was prepared for each study site, using the 6,500 to 15,500 cfs velocity set. In addition, a separate deck was constructed for each right channel for each transect for Posse Grounds transects one through eight and for the main and side channel for Price transects three through five, and as discussed above, two separate decks were constructed for each left channel for each transect for Posse Grounds transects one through eight. For the sites above ACID, separate decks were constructed for two conditions: 1) with the ACID Dam boards in; and 2) with the ACID Dam boards out. Each of these decks contained QARD flows (the flows to be simulated) from 3,250 to 31,000 cfs. WSELs simulated for the QARD flows after calibration were entered on WSEL lines. The RHABSIM equivalent of *IFG4* was run on each deck, VAFs were examined for all of the simulated flows, and velocity statistics were computed for the lowest and highest flows and the flow for which there was a velocity set (Appendix C). The only transects that deviated significantly from the expected pattern of VAFs were Posse Grounds transects four through eight right channel and Price transect two. The following transects had minor deviations from the expected pattern of VAFs: 1) Upper Lake Redding boards in; 2) Lower Lake Redding boards out; 3) Bridge transects two and three; 4) Posse Grounds transects two and three right channel; 5) Hawes transects one through four; 6) Powerline transects one through five; and 7) Price transect four side channel. We conclude that for all of the transects with major or minor deviations in the expected pattern of VAFs, the deviations were due to compound controls[16], and thus the patterns of VAFs for all transects was acceptable. In addition, the VAF values (ranging from 0.28 to 2.41) were all within an acceptable range[17] and the velocity statistics were acceptable.

[16] As noted above, the compound controls consist of the channel at the transects controlling the WSELs at low flows and a downstream hydraulic control controlling the WSELs at high flows. The applicable downstream hydraulic controls were: 1) ACID Dam for the Upper and Lower Lake Redding sites; 2) Bridge transect one for Bridge transects two and three; 3) Posse Grounds transect one right channel for Posse Grounds transects two through eight right channel; 4) a transverse bar which continued below the site for Hawes transects one through four; 5) a downstream transverse bar for Powerline transects one through five; 6) Price transect one for Price transect two; and 7) Price transect three side channel for Price transect four side channel.

[17] VAFs are considered acceptable if they fall within the range of 0.2 to 5.0.

RESULTS

The final products for this report are the calibrated RHABSIM decks for the spawning sites between Keswick Dam and Battle Creek. These decks will be used in the future with habitat suitability criteria (which are still in the process of development) to predict the amount of physical habitat for spawning chinook salmon between Keswick Dam and Battle Creek for flows ranging from 3,250 to 31,000 cfs.

The names of the final RHABSIM decks are listed below.

ACIDOUT.rhb/rsr/rwl
SALTCR.rhb/rsr/rwl
ACID408.rhb/rsr/rwl
ACID408a.rhb/rsr/rwl
BRIDGE.rhb/rsr/rwl
POSSE(1,2,3,4,5,6,7,8)LL.rhb/rsr/rwl
POSSE(1,2,3,4,5,6,7,8)LH.rhb/rsr/rwl
POSSE(1,2,3,4,5,6,7,8)R.rhb/rsr/rwl
POSSE910.rhb/rsr/rwl
HAWES.rhb/rsr/rwl
POWER.rhb/rsr/rwl
PRICE12.rhb/rsr/rwl
PRICE3M.rhb/rsr/rwl
PRICE3S.rhb/rsr/rwl
PRICE45M.rhb/rsr/rwl
PRICE45S.rhb/rsr/rwl

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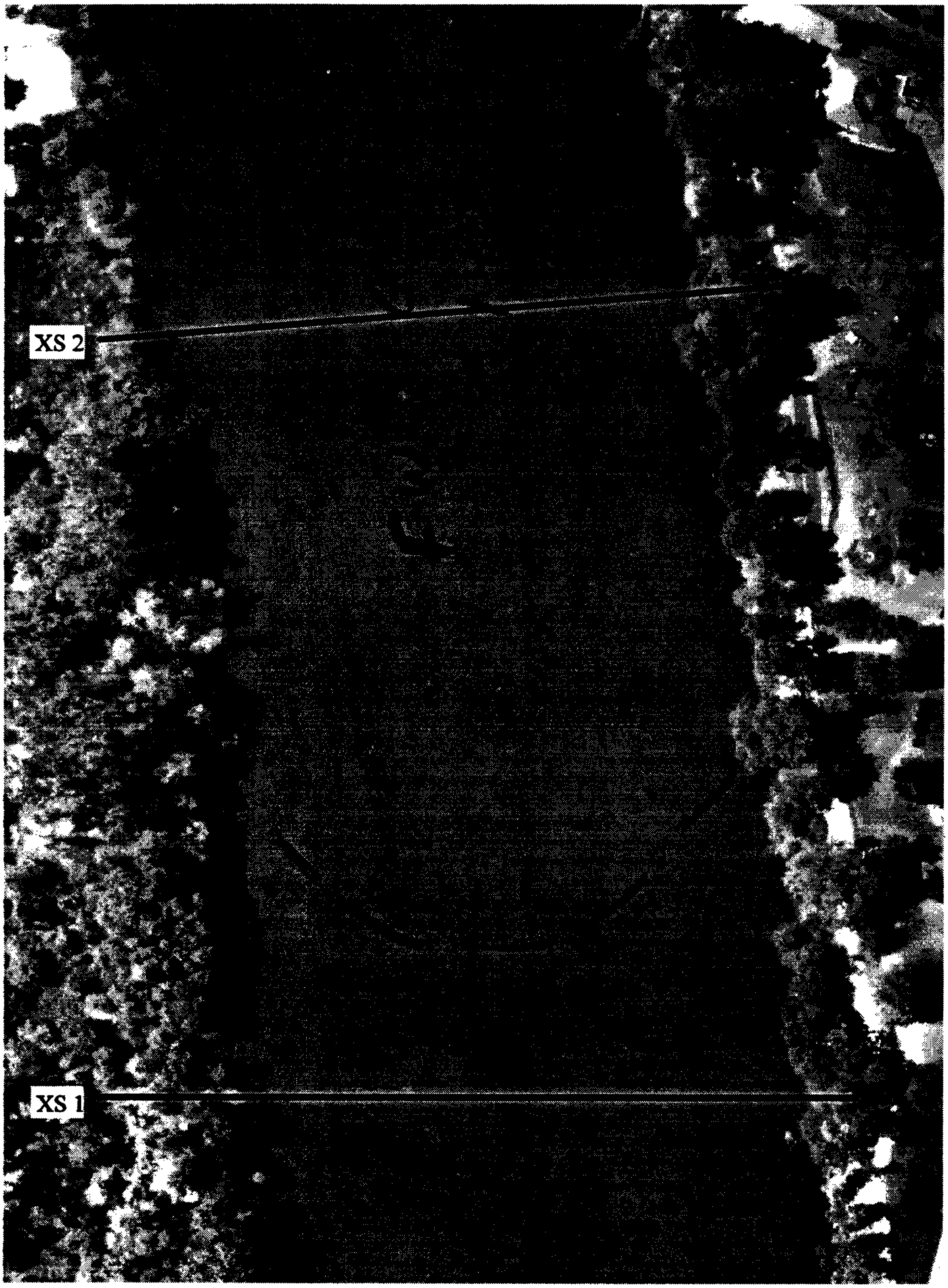
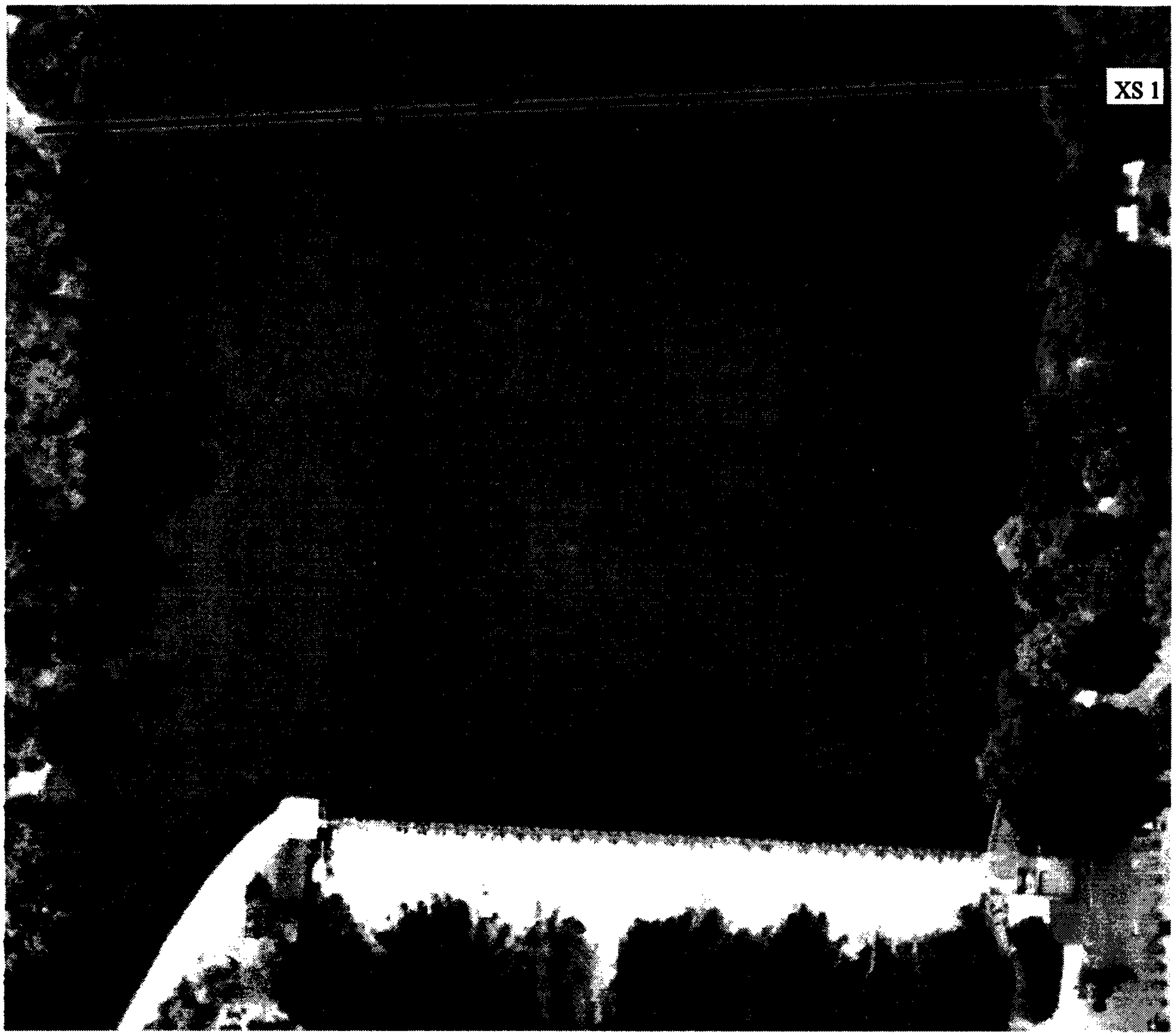
APPENDIX A
STUDY SITE AND TRANSECT LOCATIONS

Salt Creek Site

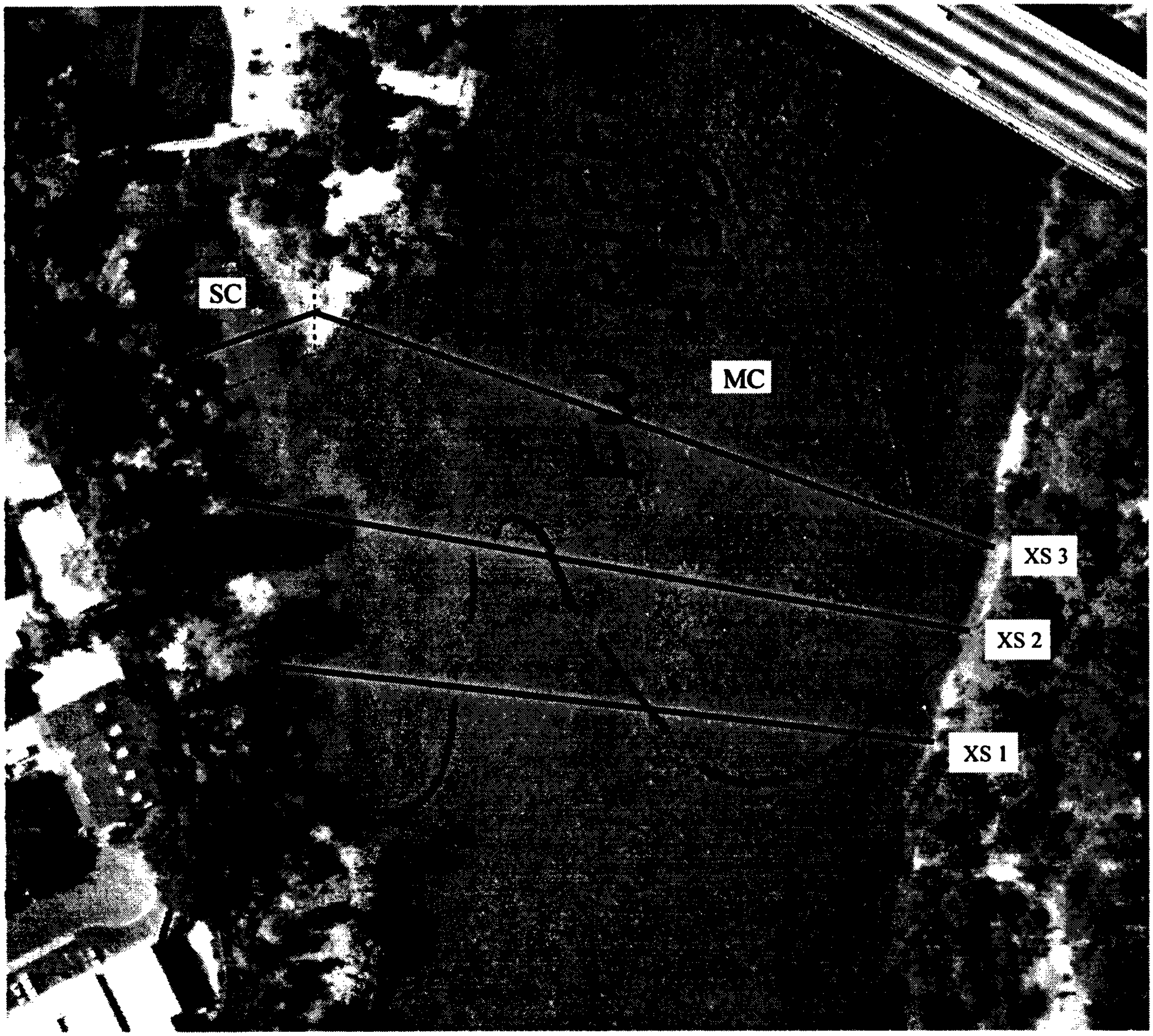
Upper Lake Redding Site



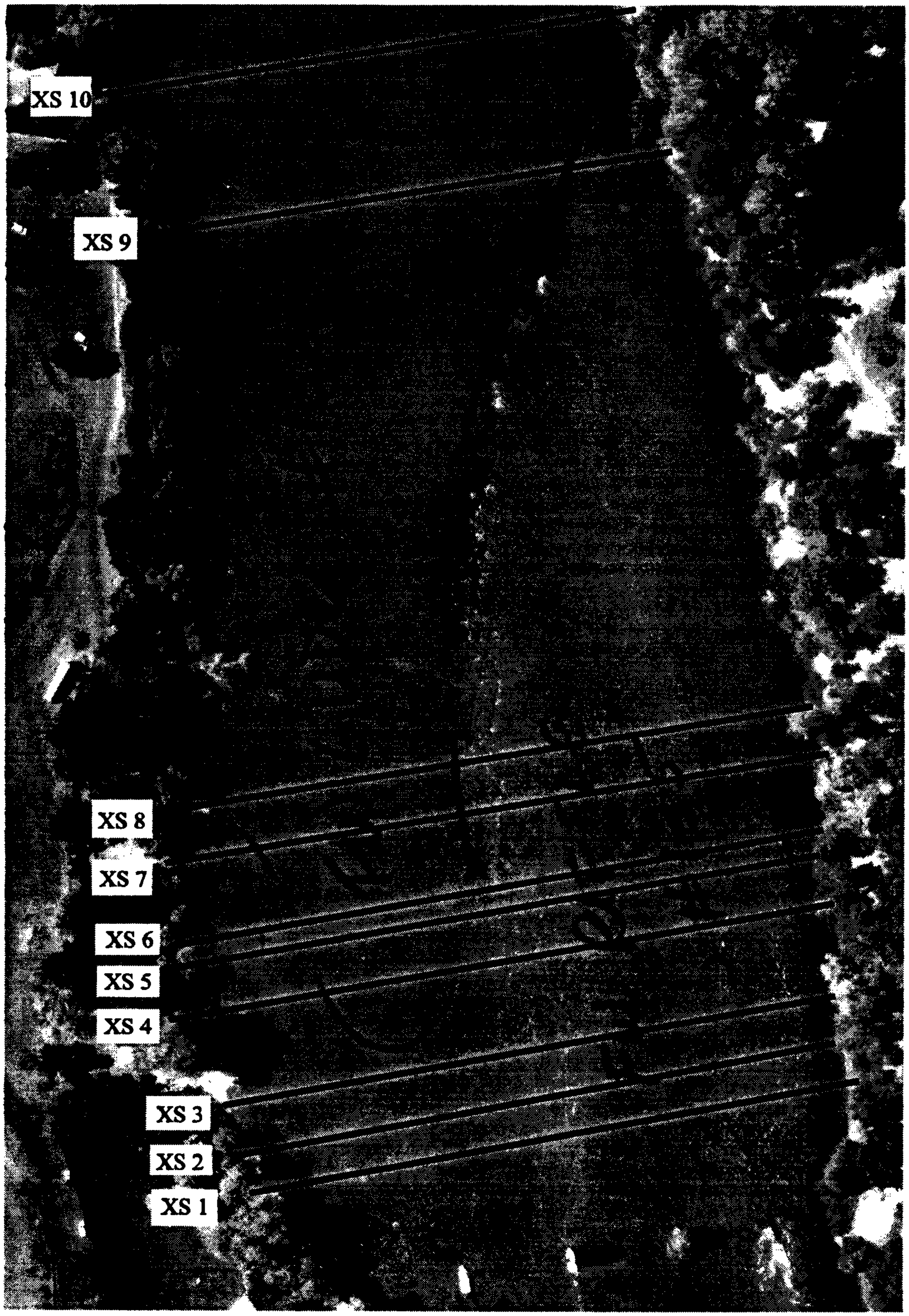
Lower Lake Redding Site



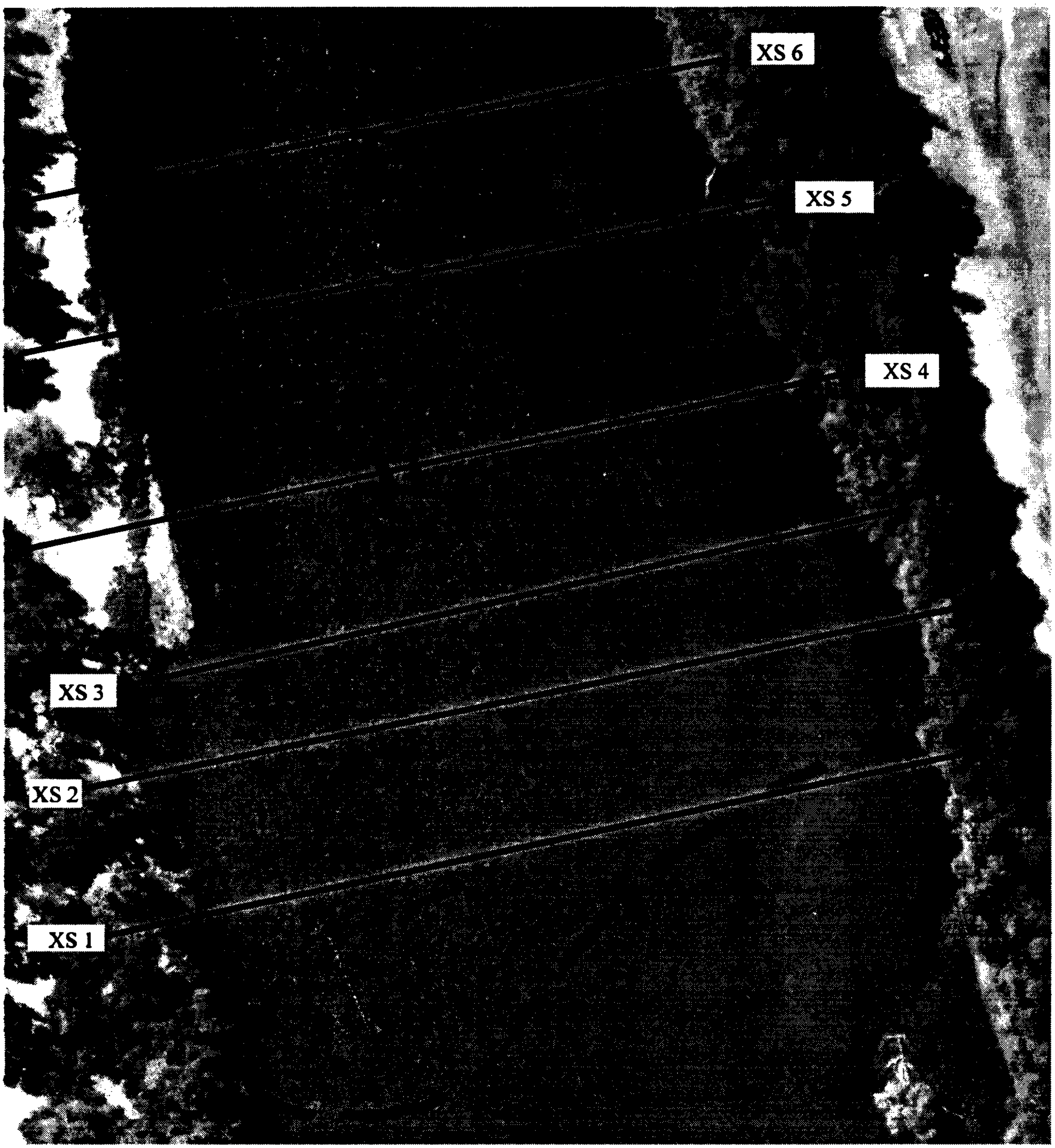
Bridge Riffle Site



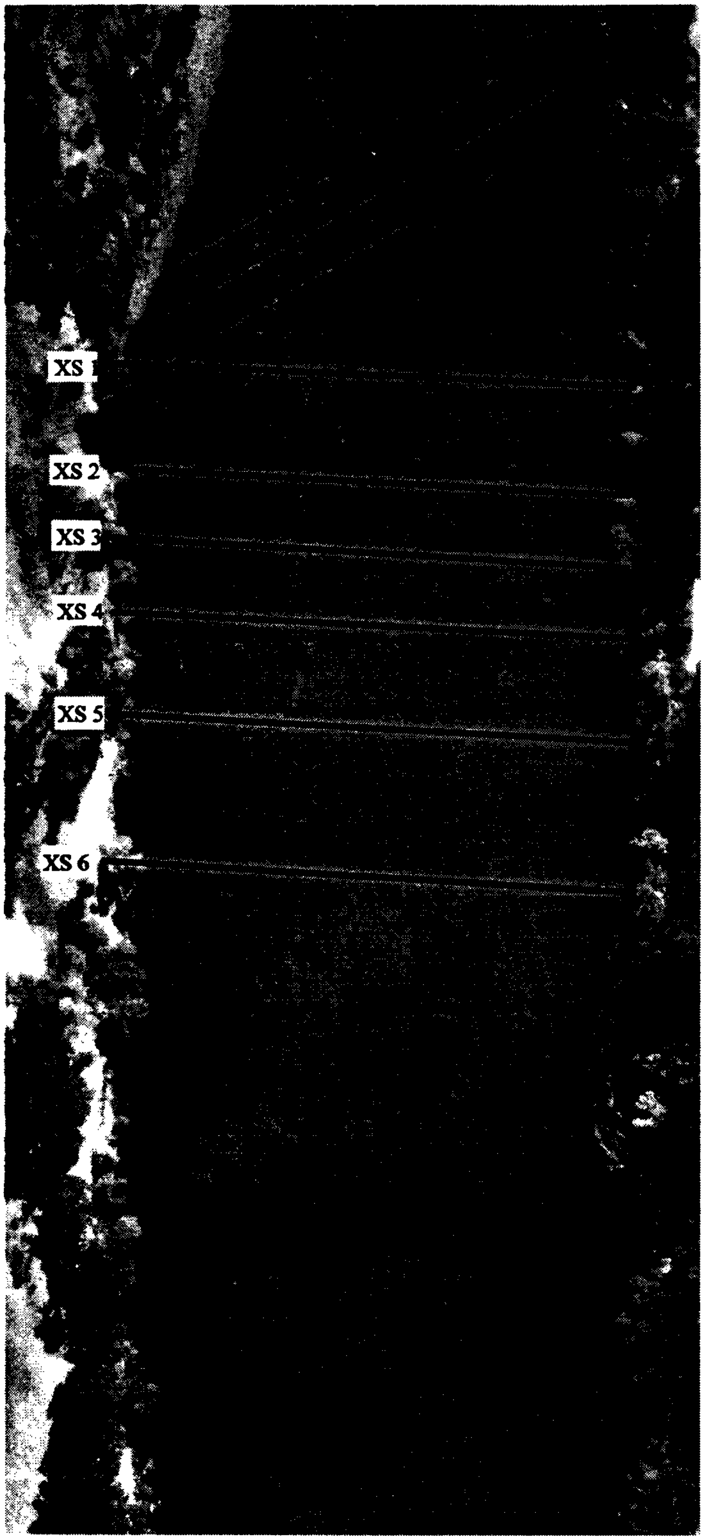
Posse Grounds Site



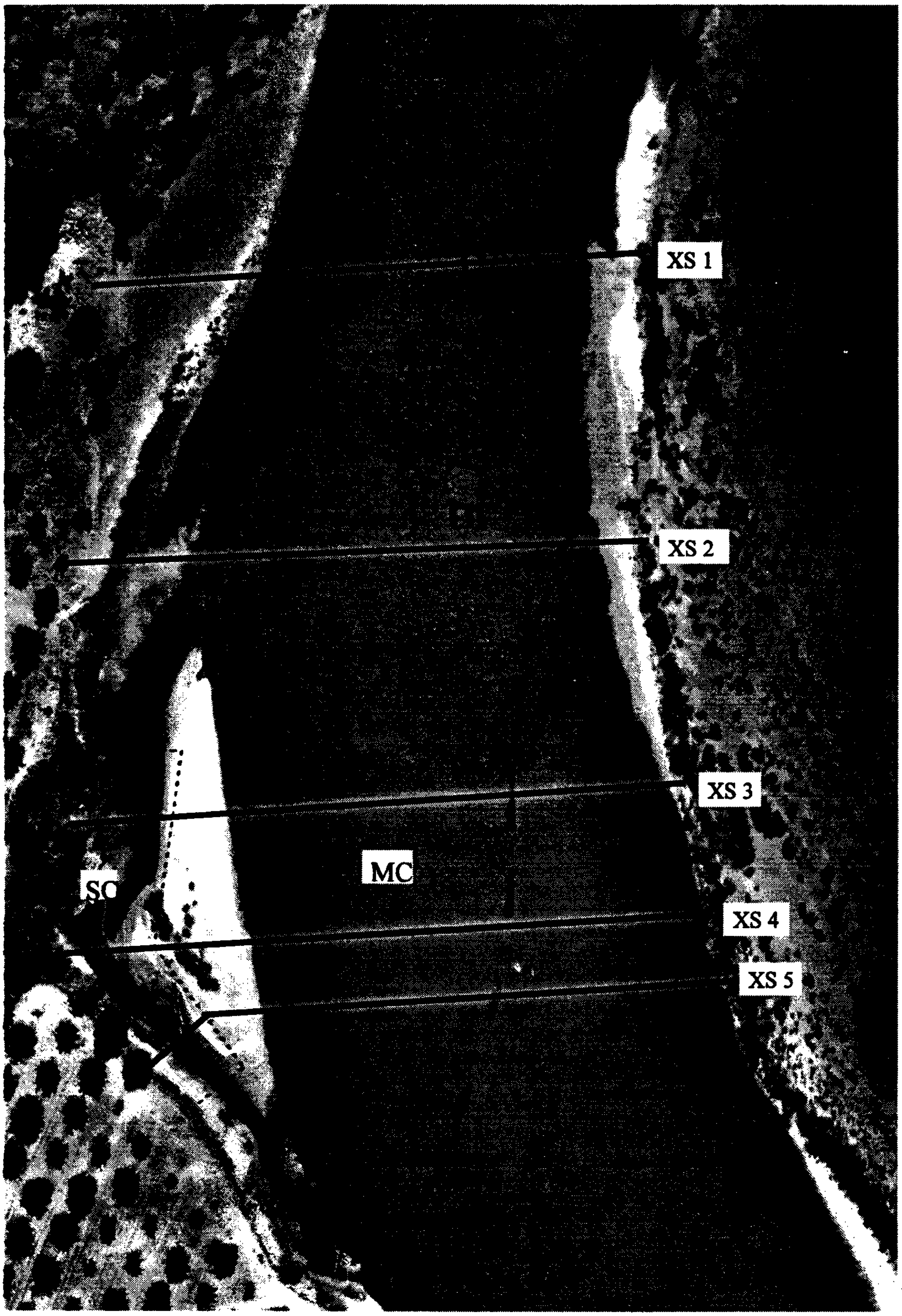
Above Hawes Hole Study Site



Powerline Riffle Site



Price Riffle Site



APPENDIX B
WSEL CALIBRATION

Calibration Methods and Parameters Used

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Salt Cr[18]	1	3250-31000	4340, 14900, 29855	IFG4	---
Salt Cr[19]	1	3250-31000	6580, 9513, 14600	IFG4	---
Upper LR[18]	1, 2	3250-31000	4308, 13568, 29823	IFG4	---
Upper LR[19]	1, 2	3250-31000	6548, 9481,13568, 14568	WSP	n = 0.02, 6548 RM = 0.65, 9481 RM = 1, 13568 RM = 1.51, 14568 RM = 1.64
Lower LR[18]	1	3250-31000	4308, 13568, 29823	IFG4	---
Lower LR[19]	1	3250-21000	6548, 9481, 13568, 14568	IFG4	---
Lower LR[19]	1	23000-31000	14568	WSP	XS1 WSEL = ACID Dam WSEL
Bridge	1	3250-9000	4075, 9199	MANSQ	$\beta = 0.392$, CALQ = 4075
Bridge	2	3250-9000	4075, 9199	MANSQ	$\beta = 0.285$, CALQ = 4075
Bridge	3	3250-9000	4075, 9094	WSP	n = 0.07, 4075 RM = 1.5, 9094 RM = 0.53
Bridge	1	10000-31000	9199, 14454, 35030	IFG4	---
Bridge	2	10000-31000	9199, 15149, 35030	IFG4	---
Bridge	3	10000-31000	9094, 14870, 34300	IFG4	---
Posse	1 LC	3250-9000	4281, 7629, 9199	IFG4	---
Posse	2 LC	3250-9000	4281, 8364, 9199	IFG4	---
Posse	3 LC	3250-13000	4281, 8364, 13915	IFG4	---
Posse	4 LC	3250-6500	4281, 8364, 13915	IFG4	---
Posse	5-6 LC	3250-9000	4281, 8422, 9199	IFG4	---
Posse	7 LC	3250-9000	4281, 7815, 9199	IFG4	---
Posse	8 LC	3250-9000	4281, 8266, 9199	IFG4	---

[18] Boards out at ACID

[19] Boards in at ACID

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Posse	1-2 LC	10000-31000	9199, 13915, 35059	IFG4	---
Posse	3 LC	14000-31000	13915, 35059	WSP	XS3 WSEL = XS2 WSEL
Posse	4 LC	7000-31000	4182, 8364, 13915, 35059	WSP	n = 0.04, 4182 RM =1.02, 8364 RM = 0.73, 13915 RM = 0.57, 35059 RM = 0.36
Posse	5-8 LC	10000-31000	9199, 13915, 35059	IFG4	---
Posse	1 RC	3250-7500	4281, 7629	MANSQ	β = 0.13, CALQ = 7629
Posse	2-3 RC	3250-8000	4281, 8364	MANSQ	β = 0.0, CALQ = 8364
Posse	4 RC	3250-21000	4281, 8364, 14365, 25100	IFG4	---
Posse	5-6 RC	3250-8000	4281, 8422	WSP	XS 4-6 n = 0.05, 4281 RM =1.01, 8422 RM = 0.95
Posse	7 RC	3250-7500	4281, 7815	WSP	XS 4-6 n = 0.05, XS 7 n = 0.04, 4281 RM =1.01, 7815 RM = 0.99
Posse	8 RC	3250-25000	4281, 8266,14365, 25100	IFG4	---
Posse	1 RC	8000-31000	7629,14365, 25100	IFG4	---
Posse	2-3 RC	9000-31000	8364,14365, 25100	IFG4	---
Posse	4 RC	23000-31000	25100	WSP	XS4 WSEL = XS3 WSEL
Posse	5-6 RC	9000-31000	8422,14365, 25100	IFG4	---
Posse	7 RC	8000-31000	7815, 14365, 25100	IFG4	---
Posse	8 RC	27000-31000	25100	IFG4	---
Posse	9	3250-4750	4281	WSP	XS9 WSEL = XS8LC WSEL
Posse	9	5000-9000	4281, 9199	MANSQ	β = 0.5, CALQ = 9199
Posse	10	3250-9000	4281, 9199	WSP	n = 0.04, 4281 RM = 1.45, 9199 RM = 0.2
Posse	9-10	10000-31000	9199, 14586, 35059	IFG4	---
Hawes	1	3250-8000	4542, 8293	MANSQ	β = 0.455, CALQ = 8293
Hawes	2	3250-8000	4542, 8293	MANSQ	β = 0.26, CALQ = 8293
Hawes	3	3250-8000	4542, 8320	MANSQ	β = 0.425, CALQ = 8320

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Hawes	4	3250-8000	4542, 8320	MANSQ	$\beta = 0.5$, CALQ = 8320
Hawes	5	3250-8000	4542, 8320	MANSQ	$\beta = 0.475$, CALQ = 8320
Hawes	6	3250-8000	4542, 8320	MANSQ	$\beta = 0.5$, CALQ = 8320
Hawes	1-2	9000-14000	8293, 10226, 14620	IFG4	---
Hawes	3-6	9000-14000	8320, 10226, 14620	IFG4	---
Hawes	1-6	15000-31000	14620, 26106, 36589	IFG4	---
Powerline	1	3250-10000	4950, 10354	MANSQ	$\beta = 0.001$, CALQ = 10354
Powerline	2	3250-10000	4950, 10354	MANSQ	$\beta = 0.07$, CALQ = 10354
Powerline	3	3250-10000	4950, 10354	MANSQ	$\beta = 0.115$, CALQ = 10354
Powerline	4	3250-10000	4950, 10354	MANSQ	$\beta = 0.135$, CALQ = 10354
Powerline	5	3250-10000	4950, 10354	MANSQ	$\beta = 0.195$, CALQ = 10354
Powerline	6	3250-10000	4950, 10354	MANSQ	$\beta = 0.2$, CALQ = 10354
Powerline	1-2	11000-31000	10354, 15097, 38281	IFG4	---
Powerline	3-6	11000-31000	10354, 14628, 38281	IFG4	---
Price	1-2	3250-8000	4819, 6844, 8953	IFG4	---
Price	1-2	9000-31000	8953, 14371, 41070	IFG4	---
Price	3 SC	5000-14000	6844, 8953, 14389	IFG4	---
Price	3 SC	15000-31000	14389, 41070	MANSQ	$\beta = 0.065$, CALQ = 41070
Price	3-5 MC	3250-13000	4819, 6844, 8953, 14389	IFG4	---
Price	3 MC	14000-31000	14389, 41070	WSP	n = 0.06, 14389 RM = 1.045, 41070 RM = 0.52
Price	4-5 SC	5000-31000	6844, 8953, 14389, 41070	IFG4	---
Price	4-5 MC	14000-31000	14389, 41070	WSP	n = 0.04, 14389 RM = 0.92, 41070 RM = 0.55

Salt Creek Site - Boards Out

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4340 cfs	14900 cfs	29855 cfs	Difference (measured vs. pred. WSELs) 4340 cfs	14900 cfs	29855 cfs
1	2.54	0.51	0.3	0.8	0.5	0.01	0.04	0.03

Salt Creek Site - Boards In

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 6580 cfs	9513 cfs	14600 cfs	Difference (measured vs. pred. WSELs) 6580 cfs	9513 cfs	14600 cfs
1	1.57	0.69	0.5	1.0	0.5	0.02	0.05	0.03

Upper Lake Redding Site - Boards Out

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4308 cfs	14868 cfs	29823 cfs	Difference (measured vs. pred. WSELs) 4308 cfs	14868 cfs	29823 cfs
1	2.08	0.73	0.6	1.1	0.7	0.01	0.04	0.04
2	2.05	0.35	0.2	0.5	0.3	None	0.02	0.02

Upper Lake Redding Site - Boards In

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 6548 cfs	9481 cfs	13568 cfs	14568 cfs	Difference (measured vs. pred. WSELs) 6548 cfs	9481 cfs	13568 cfs	14568 cfs
1	—	—	—	—	—	—	0.04	None	0.03	0.06
2	—	—	—	—	—	—	0.07	0.02	0.05	0.05

Lower Lake Redding Site - Boards Out

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4308 cfs	14868 cfs	29823 cfs	Difference (measured vs. pred. WSELs) 4308 cfs	14868 cfs	29823 cfs
1	1.40	0.11	0.1	0.2	0.1	None	0.01	0.01

Lower Lake Redding Site - Boards In

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 6548 cfs	9481 cfs	13568 cfs	14568 cfs	Difference (measured vs. pred. WSELs) 6548 cfs	9481 cfs	13568 cfs	14568 cfs
1	1.32	1.93	0.8	1.5	3.0	2.3	0.02	0.05	0.16	0.11

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 14568 cfs	Difference (measured vs. pred. WSELs) 14568 cfs
1	—	—	—	0.04

Bridge Riffle Site

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4075 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4075 cfs	9199 cfs
1	---	0	0	0	None	None
2	---	0	0	0	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4075 cfs	9094 cfs	Difference (measured vs. pred. WSELs) 4075 cfs	9094 cfs
3	---	---	---	---	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 9199 cfs	14454 cfs	35030 cfs	Difference (measured vs. pred. WSELs) 9199 cfs	14454 cfs	35030 cfs
1	2.21	0.39	0.4	0.6	0.2	0.01	0.02	0.01

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 9199 cfs	15149 cfs	35030 cfs	Difference (measured vs. pred. WSELs) 9199 cfs	15149 cfs	35030 cfs
2	2.23	0.08	0.1	0.1	0.0	None	0.01	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 9199 cfs	14870 cfs	34300 cfs	Difference (measured vs. pred. WSELs) 9199 cfs	14870 cfs	34300 cfs
3	2.26	0.99	1.0	1.5	0.5	0.03	0.06	0.03

Posse Grounds Site

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	7629 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	7629 cfs	9199 cfs
1 LC	2.92	0.02	0.0	0.0	0.0	None	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	8364 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	8364 cfs	9199 cfs
2 LC	3.36	4.03	0.2	5.9	6.0	None	0.05	0.05

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	8364 cfs	13915 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	8364 cfs	13915 cfs
3 LC	3.22	0.42	0.3	0.6	0.4	Non e	0.01	None
4 LC	3.31	4.00	2.9	6.2	3.1	0.02	0.06	0.04

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	8422 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	8422 cfs	9199 cfs
5 LC	3.84	4.02	0.1	5.9	6.1	None	0.05	0.05
6 LC	3.98	1.22	0.2	1.8	1.7	None	0.02	0.01

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	7815 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	7815 cfs	9199 cfs
7 LC	4.03	3.03	0.7	4.4	3.9	None	0.04	0.03

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	8266 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	8266 cfs	9199 cfs
8 LC	3.76	4.76	0.2	6.9	7.2	None	0.07	0.06

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 9199 cfs	13915 cfs	35059 cfs	Difference (measured vs. pred. WSELs) 9199 cfs	13915 cfs	35059 cfs
1 LC	2.08	1.99	2.1	3.0	0.9	0.03	0.06	0.03
2 LC	2.11	0.47	0.5	0.7	0.2	0.01	0.01	0.01
5 LC	2.39	0.57	0.6	0.9	0.3	0.01	0.02	0.01
6 LC	2.45	0.26	0.3	0.4	0.1	None	0.01	None
7 LC	2.51	0.86	0.9	1.3	0.4	0.01	0.02	0.01
8 LC	2.58	1.51	1.5	2.2	0.7	0.02	0.04	0.02

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 13915 cfs	35059 cfs	Difference (measured vs. pred. WSELs) 13915 cfs	35059 cfs
3 LC	—	—	—	—	0.02	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4182 cfs	8364 cfs	13915 cfs	35059 cfs	Difference (measured vs. pred. WSELs) 4182 cfs	8364 cfs	13915 cfs	35059 cfs
4 LC	—	—	—	—	—	—	0.01	0.01	0.10	0.10

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	Difference (measured vs. pred. WSELs) 4281 cfs
9	—	—	—	0.04

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4281 cfs	9199 cfs	Difference (measured vs. pred. WSELs) 4281 cfs	9199 cfs
9	—	2.91	5.8	0	0.09	None
10	—	—	—	—	None	0.02

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 9199 cfs	14586 cfs	35059 cfs	Difference (measured vs. pred. WSELs) 9199 cfs	14586 cfs	35059 cfs
9	2.82	0.10	0.1	0.2	0.0	None	0.01	None
10	2.84	0.16	0.2	0.2	0.1	None	0.01	None

Above Hawes Hole Site

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4542 cfs	8293 cfs	Difference (measured vs. pred. WSELs) 4542 cfs	8293 cfs
1	---	0	0	0	None	None
2	---	0	0	0	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4542 cfs	8320 cfs	Difference (measured vs. pred. WSELs) 4542 cfs	8320 cfs
3	---	0	0	0	None	None
4	---	1.74	3.5	0	0.04	None
5	---	0	0	0	None	None
6	---	0.64	1.3	0	0.02	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 8293 cfs	10226 cfs	14620 cfs	Difference (measured vs. pred. WSELs) 8293 cfs	10226 cfs	14620 cfs
1	2.82	1.70	2.5	1.1	1.4	0.06	0.03	0.03
2	2.66	0.15	0.2	0.1	0.1	0.01	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 8320 cfs	10226 cfs	14620 cfs	Difference (measured vs. pred. WSELs) 8320 cfs	10226 cfs	14620 cfs
3	2.71	0.74	1.1	0.4	0.7	0.03	0.01	0.01
4	2.73	1.63	2.4	1.1	1.4	0.06	0.03	0.03
5	2.68	0.61	0.9	0.3	0.6	0.02	0.01	0.01
6	2.75	0.59	0.9	0.3	0.5	0.02	0.01	0.01

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 14620 cfs	26106 cfs	36589 cfs	Difference (measured vs. pred. WSELs) 14620 cfs	26106 cfs	36589 cfs
1	2.06	0.25	0.1	0.4	0.2	0.01	0.02	0.01
2	1.91	0.61	0.4	0.9	0.6	0.01	0.04	0.03
3	1.90	1.20	0.7	1.8	1.1	0.03	0.09	0.06
4	1.92	1.35	0.8	2.0	1.2	0.03	0.10	0.07
5	2.16	1.29	0.8	2.0	1.2	0.03	0.09	0.06
6	2.18	0.18	0.1	0.3	0.2	None	0.01	0.01

Powerline Riffle Site

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4950 cfs	10354 cfs	Difference (measured vs. pred. WSELs) 4950 cfs	10354 cfs
1	—	1.26	2.5	0	0.05	None
2	—	0	0	0	None	None
3	—	0	0	0	None	None
4	—	0	0	0	None	None
5	—	0	0	0	None	None
6	—	0	0	0	None	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 10354 cfs	15097 cfs	38281 cfs	Difference (measured vs. pred. WSELs) 10354 cfs	15097 cfs	38281 cfs
1	1.83	0.08	0.1	0.1	0.0	None	0.01	None
2	1.80	0.67	0.7	1.0	0.3	0.03	0.05	0.02

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 10354 cfs	14628 cfs	38281 cfs	Difference (measured vs. pred. WSELs) 10354 cfs	14628 cfs	38281 cfs
3	1.84	1.15	1.3	1.7	0.4	0.05	0.07	0.03
4	1.83	1.24	1.4	1.9	0.5	0.05	0.08	0.03
5	1.85	0.66	0.7	1.0	0.3	0.03	0.06	0.02
6	1.94	0.46	0.5	0.7	0.2	0.02	0.03	0.01

Price Riffle Site

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4819 cfs	6844 cfs	8953 cfs	Difference (measured vs. pred. WSELs) 4819 cfs	6844 cfs	8953 cfs
1	2.64	0.95	0.7	1.4	0.8	0.01	0.03	0.02
2	1.50	0.30	0.2	0.4	0.3	None	0.01	0.01

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 8953 cfs	14371 cfs	41070 cfs	Difference (measured vs. pred. WSELs) 8953 cfs	14371 cfs	41070 cfs
1	2.42	2.25	2.4	3.4	1.0	0.07	0.12	0.05
2	1.84	1.27	1.3	1.9	0.6	0.03	0.07	0.04

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 14389 cfs	41070 cfs	Difference (measured vs. pred. WSELs) 14389 cfs	41070 cfs
3 SC	—	0	0	0	None	None
3 MC	—	---	—	—	None	None
4 MC	—	---	—	—	0.06	None
5 MC	—	---	—	—	0.05	None

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 6844 cfs	8953 cfs	14389 cfs	Difference (measured vs. pred. WSELs) 6844 cfs	8953 cfs	14389 cfs
3 SC	1.68	2.34	2.0	3.6	1.5	0.01	0.03	0.03

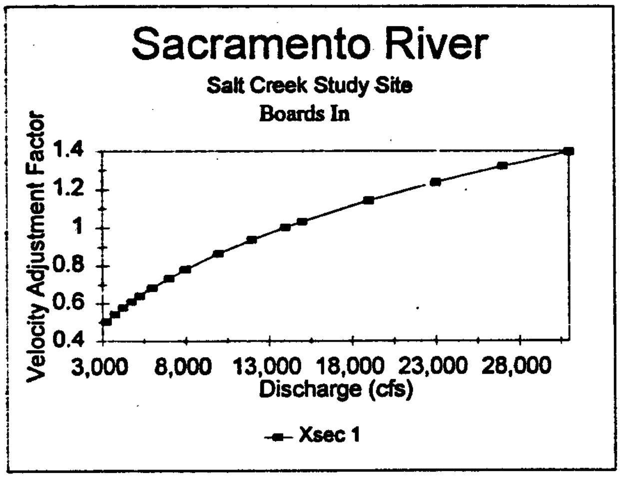
XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 6844 cfs	8953 cfs	14389 cfs	41070 cfs	Difference (measured vs. pred. WSELs) 6844 cfs	8953 cfs	14389 cfs	41070 cfs
4 SC	1.79	3.08	4.3	5.1	0.9	1.9	0.02	0.04	0.02	0.09
5 SC	1.99	1.70	1.0	2.8	2.4	0.5	0.01	0.03	0.04	0.02

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 4819 cfs	6844 cfs	8953 cfs	14389 cfs	Difference (measured vs. pred. WSELs) 4819 cfs	6844 cfs	8953 cfs	14389 cfs
3 MC	2.34	3.00	4.0	4.7	1.4	1.9	0.08	0.09	0.03	0.05
4 MC	2.50	2.10	2.4	2.0	2.3	1.7	0.04	0.04	0.05	0.04
5 MC	2.41	2.00	2.3	1.9	2.1	1.6	0.04	0.04	0.05	0.04

APPENDIX C
VELOCITY CALIBRATION

SALT CREEK STUDY SITE - BOARDS IN

Discharge	Velocity Adjustment Factors Xsec 1
3,250	0.50
3,750	0.54
4,250	0.58
4,750	0.61
5,250	0.64
6,000	0.68
7,000	0.73
8,000	0.78
10,000	0.86
12,000	0.94
14,000	1.00
15,000	1.03
19,000	1.14
23,000	1.24
27,000	1.32
31,000	1.39



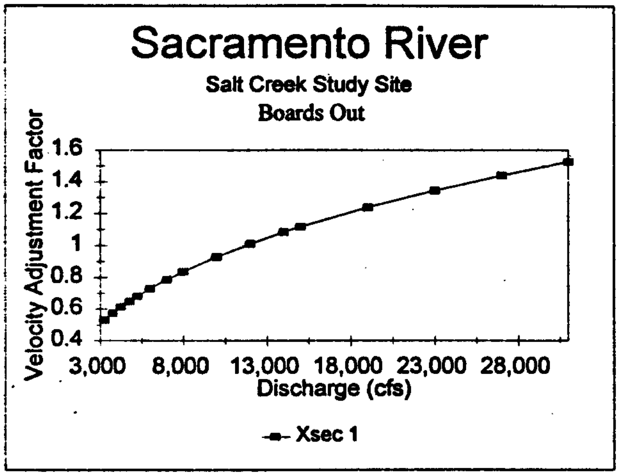
CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Salt Creek Study Site - Boards In

TRANSECT 1	meas 14,600	sim 3,250	sim 14,600	sim 31,000
		14,600 CFS VELOCITY SET USED		
avg	2.82	1.53	2.90	4.37
std dev	2.47	0.76	2.53	4.12
max	6.24	2.44	6.43	10.31
avg diff			0.08	
+/-			4.73	
max diff			0.33	

SALT CREEK STUDY SITE - BOARDS OUT

Discharge	Velocity Adjustment Factors Xsec 1
3,250	0.53
3,750	0.57
4,250	0.61
4,750	0.65
5,250	0.68
6,000	0.73
7,000	0.79
8,000	0.84
10,000	0.93
12,000	1.01
14,000	1.08
15,000	1.12
19,000	1.24
23,000	1.34
27,000	1.44
31,000	1.52



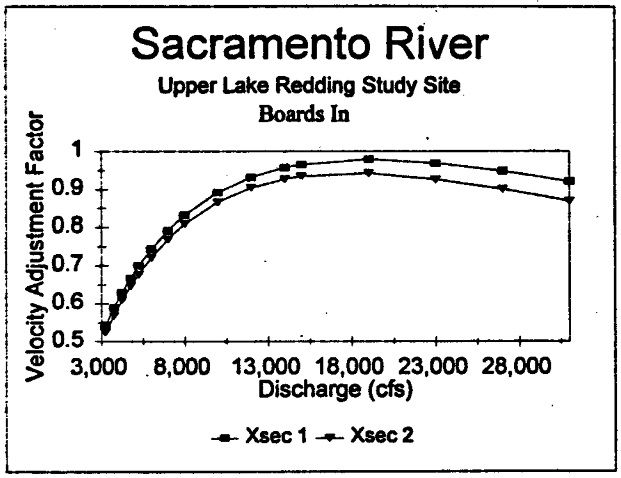
CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Salt Creek Study Site - Boards Out

TRANSECT 1	meas	14,600 CFS VELOCITY SET USED sim	sim	sim
	14,600	3,250	14,600	31,000
avg	N/A	1.61	3.06	4.88
std dev	N/A	0.76	2.64	4.34
max	N/A	2.53	6.73	10.92
avg diff			N/A	
+/-			N/A	
max diff			N/A	

UPPER LAKE REDDING STUDY SITE - BOARDS IN

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
3,250	0.54	0.52
3,750	0.59	0.57
4,250	0.63	0.61
4,750	0.67	0.65
5,250	0.70	0.68
6,000	0.74	0.72
7,000	0.79	0.77
8,000	0.83	0.81
10,000	0.89	0.87
12,000	0.93	0.90
14,000	0.96	0.93
15,000	0.97	0.93
19,000	0.98	0.94
23,000	0.97	0.93
27,000	0.95	0.90
31,000	0.92	0.87



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Upper Lake Redding Study Site - Boards In

TRANSECT 1 — 14,568 CFS VELOCITY SET USED

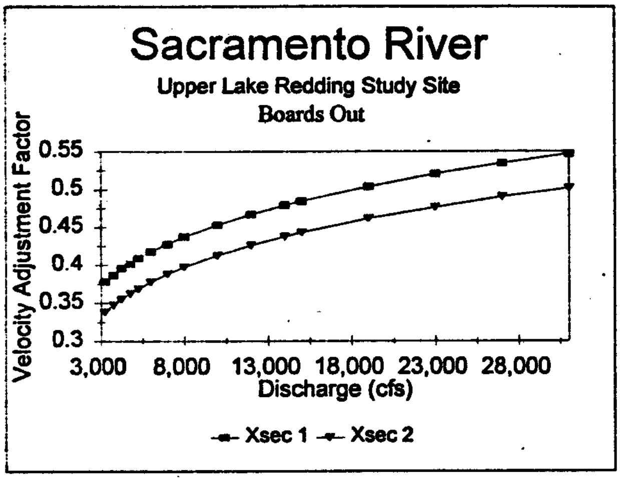
	meas	sim	sim	sim
	14,568	3,250	14,568	31,000
avg	2.65	1.04	2.59	3.33
std dev	0.92	0.30	0.87	1.25
max	4.19	1.49	3.86	5.11
avg diff			**0.09**	
+/-			**-12.95**	
max diff			**0.33**	

TRANSECT 2 — 14,568 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,568	3,250	14,568	31,000
avg	2.87	1.08	2.72	3.49
std dev	0.85	0.29	0.81	1.10
max	4.11	1.51	4.08	5.42
avg diff			**0.15**	
+/-			**-24.98**	
max diff			**0.37**	

UPPER LAKE REDDING STUDY SITE - BOARDS OUT

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
3,250	0.38	0.34
3,750	0.39	0.35
4,250	0.40	0.36
4,750	0.40	0.36
5,250	0.41	0.37
6,000	0.42	0.38
7,000	0.43	0.39
8,000	0.44	0.40
10,000	0.45	0.41
12,000	0.47	0.43
14,000	0.48	0.44
15,000	0.48	0.44
19,000	0.50	0.46
23,000	0.52	0.48
27,000	0.53	0.49
31,000	0.55	0.50



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Upper Lake Redding Study Site - Boards Out

TRANSECT 1 14,568 CFS VELOCITY SET USED

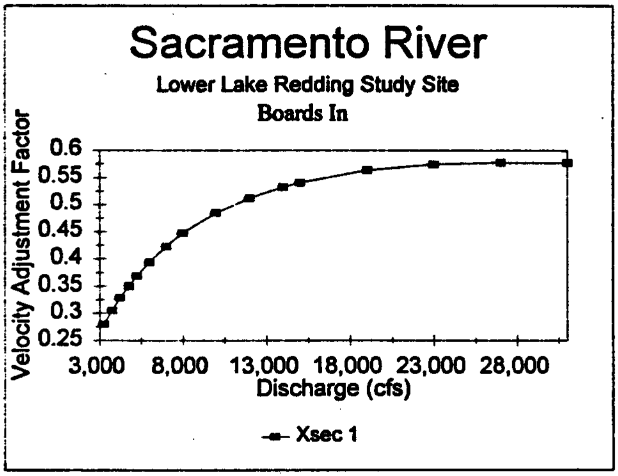
	meas 14,568	sim 3,250	sim 14,568	sim 31,000
avg	N/A	1.94	3.91	5.61
std dev	N/A	0.54	1.15	1.89
max	N/A	3.10	5.66	8.38
avg diff			N/A	
+/-			N/A	
max diff			N/A	

TRANSECT 2 14,568 CFS VELOCITY SET USED

	meas 14,568	sim 3,250	sim 14,568	sim 31,000
avg	N/A	1.91	3.90	5.65
std dev	N/A	0.46	1.14	1.80
max	N/A	2.66	5.64	8.58
avg diff			N/A	
+/-			N/A	
max diff			N/A	

LOWER LAKE REDDING STUDY SITE - BOARDS IN

Discharge	Velocity Adjustment Factors Xsec 1
3,250	0.28
3,750	0.30
4,250	0.33
4,750	0.35
5,250	0.37
6,000	0.39
7,000	0.42
8,000	0.45
10,000	0.48
12,000	0.51
14,000	0.53
15,000	0.54
19,000	0.56
23,000	0.57
27,000	0.58
31,000	0.58



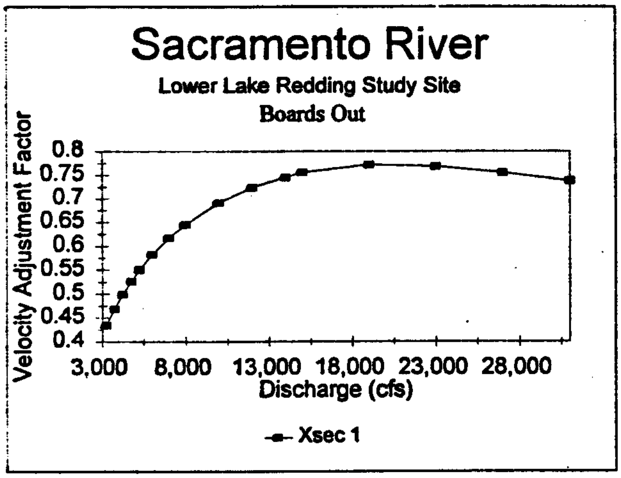
CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Lower Lake Redding Study Site - Boards In

TRANSECT 1	meas 14,568	sim 3,250	sim 14,568	sim 31,000
		14,568 CFS VELOCITY SET USED		
avg	2.22	0.74	2.11	3.05
std dev	0.88	0.38	0.83	1.10
max	3.65	1.44	3.46	4.88
avg diff			**0.11**	
+/-			**-22.45**	
max diff			**0.25**	

LOWER LAKE REDDING STUDY SITE - BOARDS OUT

Discharge	Velocity Adjustment Factors Xsec 1
3,250	0.43
3,750	0.47
4,250	0.50
4,750	0.53
5,250	0.55
6,000	0.58
7,000	0.62
8,000	0.65
10,000	0.69
12,000	0.72
14,000	0.75
15,000	0.76
19,000	0.77
23,000	0.77
27,000	0.76
31,000	0.74



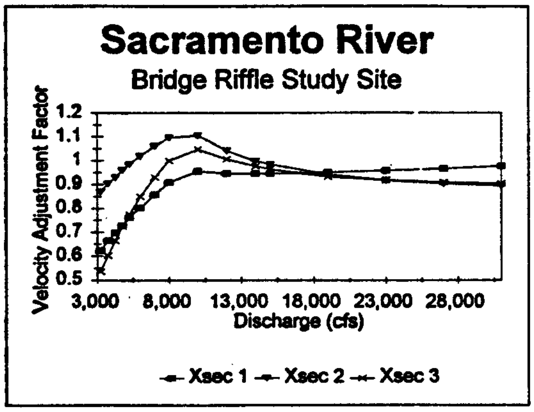
CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Lower Lake Redding Study Site - Boards Out

TRANSECT 1		14,568 CFS VELOCITY SET USED		
	meas	sim	sim	sim
	14,568	3,250	14,568	31,000
avg	N/A	2.27	5.14	6.10
std dev	N/A	0.88	2.30	2.58
max	N/A	3.92	8.83	10.83
avg diff			N/A	
+/-			N/A	
max diff			N/A	

BRIDGE RIFFLE STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2	Xsec 3
3,250	0.62	0.87	0.54
3,750	0.66	0.90	0.60
4,250	0.70	0.93	0.66
4,750	0.73	0.96	0.72
5,250	0.76	0.98	0.77
6,000	0.80	1.02	0.85
7,000	0.86	1.06	0.93
8,000	0.91	1.10	1.00
10,000	0.95	1.10	1.05
12,000	0.95	1.04	1.01
14,000	0.95	1.00	0.97
15,000	0.94	0.98	0.96
19,000	0.95	0.94	0.93
23,000	0.96	0.92	0.92
27,000	0.96	0.90	0.91
31,000	0.97	0.89	0.90



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Bridge Riffle Study Site

TRANSECT 1 — 14,454 CFS VELOCITY SET USED

	meas 14,454	sim 3,250	sim 14,454	sim 31,000
avg	4.65	1.75	4.38	5.71
std dev	2.18	1.00	2.05	3.47
max	12.50	5.44	11.77	11.96
avg diff			**0.27**	
+/-			**-48.15**	
max diff			**0.73**	

TRANSECT 2 — 15,149 CFS VELOCITY SET USED

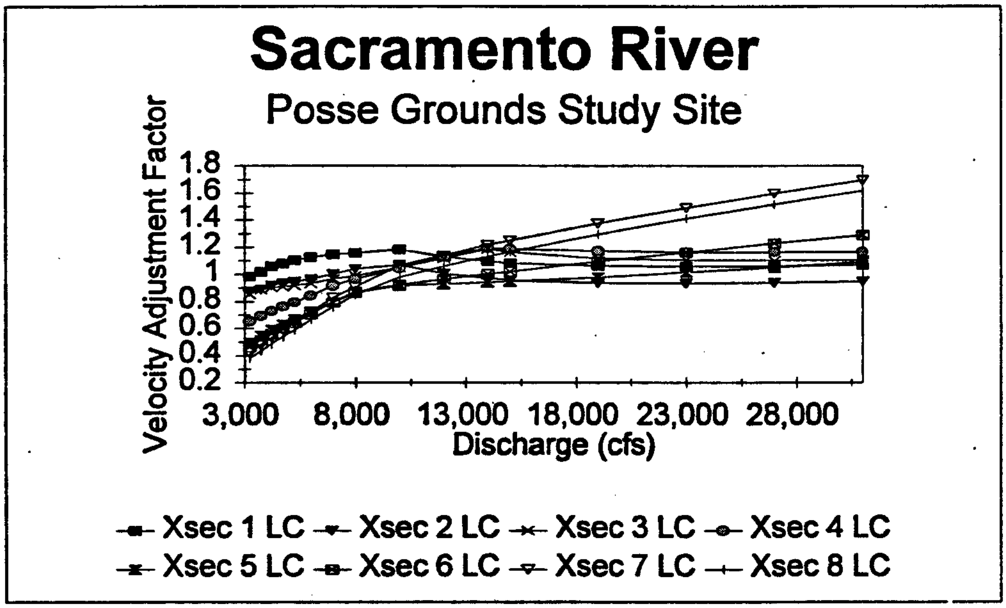
	meas 15,149	sim 3,250	sim 15,149	sim 31,000
avg	4.50	1.93	4.41	5.51
std dev	2.78	1.41	2.73	3.62
max	10.24	5.80	10.05	12.10
avg diff			**0.09**	
+/-			**-10.20**	
max diff			**0.19**	

TRANSECT 3 — 14,870 CFS VELOCITY SET USED

	meas 14,870	sim 3,250	sim 14,870	sim 31,000
avg	4.84	1.72	4.58	5.71
std dev	2.52	0.98	2.53	3.47
max	9.65	3.98	9.35	11.96
avg diff			**0.14**	
+/-			**-10.07**	
max diff			**0.30**	

POSSE GROUNDS STUDY SITE LEFT CHANNEL

Discharge	Velocity Adjustment Factors Xsec 1 LC	Xsec 2 LC	Xsec 3 LC	Xsec 4 LC	Xsec 5 LC	Xsec 6 LC	Xsec 7 LC	Xsec 8 LC
3,250	0.98	0.87	0.85	0.65	0.50	0.47	0.42	0.38
3,750	1.02	0.89	0.88	0.69	0.55	0.51	0.48	0.43
4,250	1.06	0.92	0.90	0.73	0.59	0.56	0.53	0.49
4,750	1.08	0.93	0.91	0.76	0.63	0.60	0.59	0.54
5,250	1.10	0.94	0.92	0.79	0.67	0.64	0.64	0.59
6,000	1.12	0.97	0.93	0.84	0.72	0.71	0.72	0.66
7,000	1.15	1.00	0.96	0.91	0.79	0.79	0.83	0.76
8,000	1.16	1.04	0.99	0.96	0.86	0.87	0.90	0.85
10,000	1.18	1.07	1.05	1.05	0.91	0.92	1.06	0.98
12,000	1.13	1.00	1.12	1.13	0.93	0.96	1.14	1.06
14,000	1.09	0.97	1.18	1.19	0.94	1.00	1.22	1.13
15,000	1.08	0.96	1.16	1.19	0.95	1.02	1.25	1.17
19,000	1.06	0.93	1.12	1.17	0.98	1.09	1.37	1.29
23,000	1.05	0.93	1.10	1.16	1.01	1.16	1.49	1.41
27,000	1.06	0.94	1.10	1.16	1.05	1.23	1.60	1.51
31,000	1.07	0.94	1.10	1.16	1.09	1.29	1.70	1.62



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Posse Grounds Study Site Left Channel

TRANSECT 1 LC	meas	7,629 CFS VELOCITY SET USED sim	sim	sim
	7,629	3,250	7,629	31,000
avg	2.05	1.32	2.37	5.90
std dev	0.90	0.66	1.04	2.45
max	3.77	2.36	4.37	10.97
avg diff			0.33	
+/-			10.51	
max diff			0.60	

TRANSECT 2 LC	meas	8,364 CFS VELOCITY SET USED sim	sim	sim
	8,364	3,250	8,364	31,000
avg	2.60	1.29	2.67	5.75
std dev	1.31	0.73	1.35	3.04
max	4.82	2.54	4.95	11.68
avg diff			0.07	
+/-			2.62	
max diff			0.15	

TRANSECT 3 LC	meas	8,364 CFS VELOCITY SET USED sim	sim	sim
	8,364	3,250	8,364	31,000
avg	2.55	1.25	2.56	6.28
std dev	1.12	0.72	1.12	2.76
max	4.10	2.31	4.11	11.37
avg diff			0.00	
+/-			0.12	
max diff			0.01	

TRANSECT 4 LC	meas	8,364 CFS VELOCITY SET USED sim	sim	sim
	8,364	3,250	8,364	31,000
avg	2.54	1.17	2.48	7.13
std dev	0.81	0.40	0.76	2.35
max	3.70	1.72	3.60	12.11
avg diff			0.09	
+/-			-2.15	
max diff			0.30	

TRANSECT 5 LC	meas	8,422 CFS VELOCITY SET USED sim	sim	sim
	8,422	3,250	8,422	31,000
avg	2.65	0.80	2.33	6.78
std dev	1.18	0.56	1.05	2.32
max	6.33	2.27	5.59	12.81
avg diff			0.32	
+/-			-15.77	
max diff			0.74	

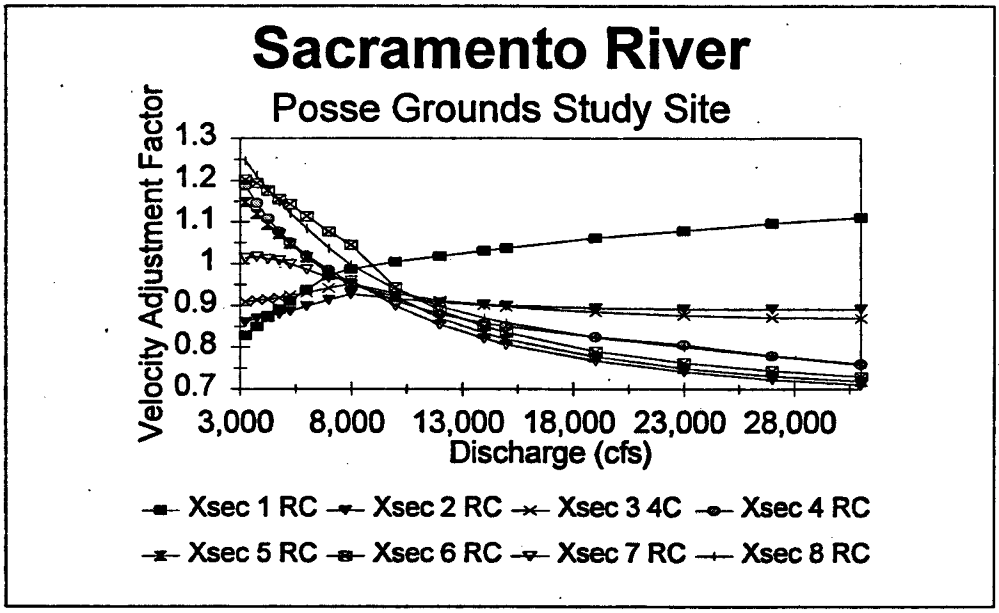
TRANSECT 6 LC	meas	8,422 CFS VELOCITY SET USED sim	sim	sim
	8,422	3,250	8,422	31,000
avg	2.35	0.74	2.13	6.04
std dev	1.21	0.46	1.10	2.60
max	4.66	1.68	4.22	10.36
avg diff			0.23	
+/-			-11.55	
max diff			0.44	

TRANSECT 7 LC	meas	7,815 CFS VELOCITY SET USED sim	sim	sim
	7,815	3,250	7,815	31,000
avg	2.12	0.65	1.92	6.90
std dev	1.05	0.40	0.95	2.43
max	6.10	2.06	5.53	16.99
avg diff			0.20	
+/-			-10.92	
max diff			0.57	

TRANSECT 8 LC	meas	8,266 CFS VELOCITY SET USED sim	sim	sim
	8,266	3,250	8,266	31,000
avg	2.41	0.72	2.07	7.32
std dev	0.93	0.29	0.81	2.64
max	4.33	1.29	3.74	14.59
avg diff			0.34	
+/-			-21.79	
max diff			0.59	

POSSE GROUNDS STUDY SITE RIGHT CHANNEL

Discharge	Velocity Adjustment Factors Xsec 1 RC	Xsec 2 RC	Xsec 3 4C	Xsec 4 RC	Xsec 5 RC	Xsec 6 RC	Xsec 7 RC	Xsec 8 RC
3,250	0.83	0.86	0.91	1.19	1.15	1.20	1.01	1.25
3,750	0.85	0.87	0.91	1.15	1.12	1.19	1.02	1.21
4,250	0.87	0.88	0.91	1.11	1.09	1.18	1.01	1.18
4,750	0.89	0.88	0.92	1.08	1.07	1.16	1.01	1.15
5,250	0.91	0.89	0.92	1.05	1.05	1.14	1.00	1.12
6,000	0.94	0.90	0.93	1.02	1.02	1.11	0.99	1.08
7,000	0.97	0.91	0.94	0.98	0.98	1.08	0.97	1.04
8,000	0.99	0.93	0.95	0.95	0.95	1.04	0.96	1.00
10,000	1.00	0.92	0.93	0.91	0.92	0.94	0.90	0.94
12,000	1.02	0.91	0.91	0.88	0.87	0.89	0.85	0.90
14,000	1.03	0.90	0.90	0.86	0.83	0.85	0.82	0.87
15,000	1.04	0.90	0.90	0.85	0.82	0.84	0.81	0.86
19,000	1.06	0.89	0.88	0.83	0.78	0.79	0.77	0.82
23,000	1.08	0.89	0.88	0.81	0.75	0.76	0.74	0.80
27,000	1.10	0.89	0.87	0.78	0.73	0.74	0.72	0.78
31,000	1.11	0.89	0.87	0.76	0.72	0.73	0.71	0.76



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Posse Grounds Study Site Right Channel

TRANSECT 1 RC	meas 7,629	7,629 CFS VELOCITY SET USED sim 3,250	sim 7,629	sim 31,000
avg	4.65	3.13	4.50	7.12
std dev	2.82	1.97	2.80	4.45
max	9.33	6.06	9.23	15.32
avg diff			0.05	
+/-			-2.25	
max diff			0.10	

TRANSECT 2 RC	meas 8,364	8,364 CFS VELOCITY SET USED sim 3,250	sim 8,364	sim 31,000
avg	5.41	3.55	5.03	6.56
std dev	3.09	2.13	2.88	4.24
max	12.79	8.57	11.91	16.29
avg diff			0.37	
+/-			-18.22	
max diff			0.88	

TRANSECT 3 RC	meas 8,364	8,364 CFS VELOCITY SET USED sim 3,250	sim 8,364	sim 31,000
avg	5.02	3.52	4.80	5.85
std dev	2.74	2.03	2.62	3.67
max	10.47	7.47	10.02	12.95
avg diff			0.22	
+/-			-8.42	
max diff			0.45	

TRANSECT 4 RC	meas 8,364	8,364 CFS VELOCITY SET USED sim 3,250	sim 8,364	sim 31,000
avg	5.62	4.89	5.38	6.56
std dev	2.57	2.23	2.44	2.84
max	10.23	9.22	9.74	11.72
avg diff			0.24	
+/-			-10.65	
max diff			0.49	

TRANSECT 5 RC	meas 8,422	8,422 CFS VELOCITY SET USED sim 3,250	sim 8,422	sim 31,000
avg	5.80	4.95	5.57	6.25
std dev	2.49	1.93	2.36	2.86
max	10.54	8.40	10.11	12.78
avg diff			0.23	
+/-			-9.08	
max diff			0.46	

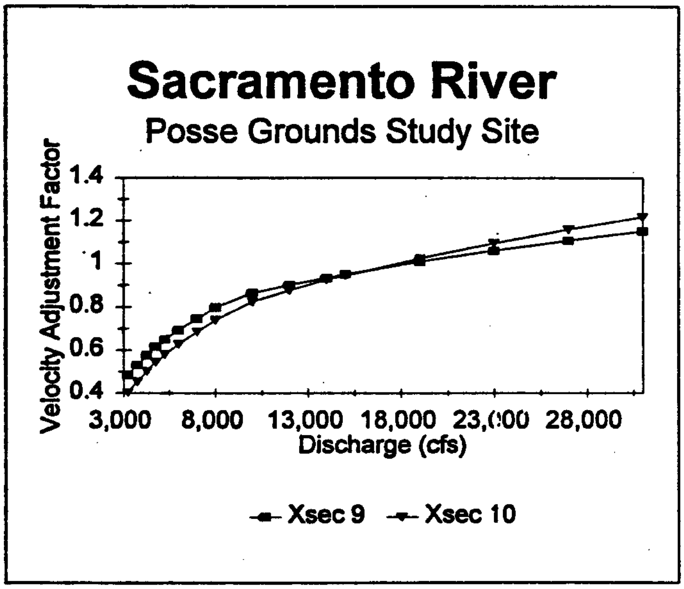
TRANSECT 6 RC	meas 8,422	8,422 CFS VELOCITY SET USED sim 3,250	sim 8,422	sim 31,000
avg	5.14	4.85	5.21	5.77
std dev	2.47	2.04	2.52	2.52
max	9.47	8.11	9.62	10.41
avg diff			0.07	
+/-			2.63	
max diff			0.15	

TRANSECT 7 RC	meas 7,815	7,815 CFS VELOCITY SET USED sim 3,250	sim 7,815	sim 31,000
avg	5.80	4.44	5.57	6.31
std dev	1.94	1.52	1.86	2.07
max	9.29	7.21	8.91	10.02
avg diff			0.23	
+/-			-14.17	
max diff			0.38	

TRANSECT 8 RC	meas 8,266	8,266 CFS VELOCITY SET USED sim 3,250	sim 8,266	sim 31,000
avg	4.68	4.02	4.63	5.26
std dev	1.89	1.78	1.87	2.12
max	8.89	8.09	8.79	9.66
avg diff			0.05	
+/-			-3.51	
max diff			0.10	

POSSE GROUNDS STUDY SITE XS 9 & 10

Discharge	Velocity Adjustment Factors Xsec 9	Xsec 10
3,250	0.48	0.40
3,750	0.53	0.45
4,250	0.58	0.50
4,750	0.62	0.54
5,250	0.65	0.58
6,000	0.69	0.63
7,000	0.74	0.68
8,000	0.80	0.74
10,000	0.86	0.82
12,000	0.90	0.88
14,000	0.93	0.92
15,000	0.95	0.94
19,000	1.01	1.02
23,000	1.06	1.10
27,000	1.11	1.16
31,000	1.15	1.22



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

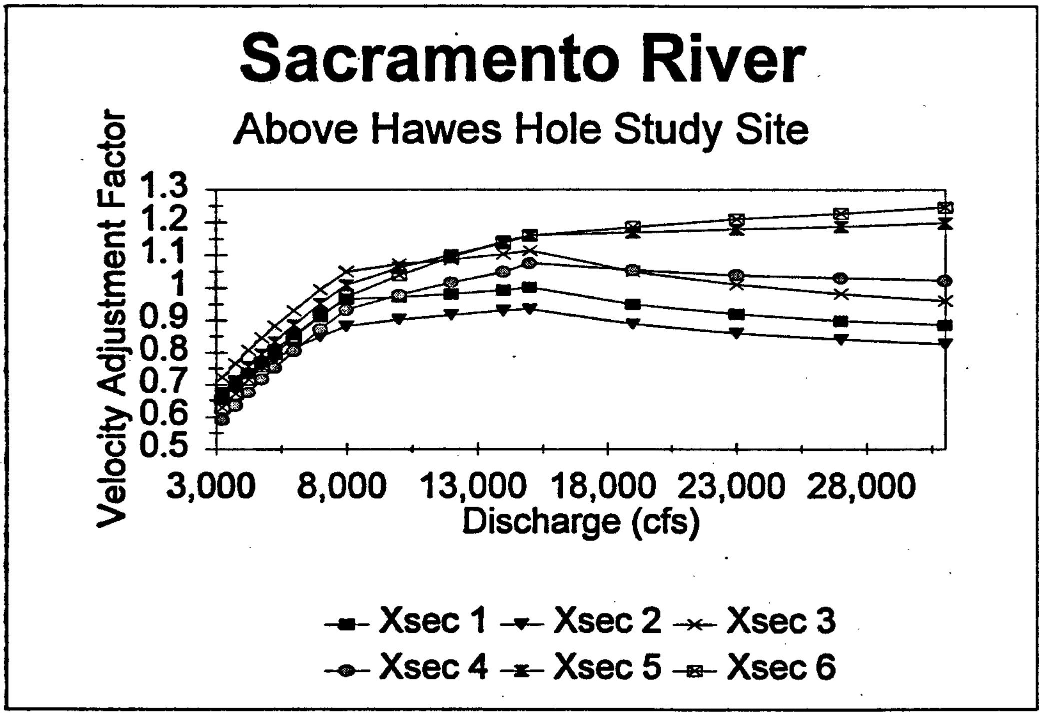
Posse Grounds Study Site XS 9 & 10

TRANSECT 9		14,586 CFS VELOCITY SET USED		
	meas 14,586	sim 3,250	sim 14,586	sim 31,000
avg	4.20	1.44	3.93	5.96
std dev	1.03	0.37	1.04	1.67
max	5.67	2.06	5.35	8.13
avg diff			**0.24**	
+/-			**-47.33**	
max diff			**0.32**	

TRANSECT 10		14,586 CFS VELOCITY SET USED		
	meas 14,586	sim 3,250	sim 14,586	sim 31,000
avg	3.76	1.18	3.52	5.42
std dev	1.66	0.51	1.55	2.57
max	5.91	1.89	5.52	8.61
avg diff			**0.25**	
+/-			**-30.93**	
max diff			**0.39**	

ABOVE HAWES HOLE STUDY SITE

	Velocity Adjustment Factors					
Discharge	Xsec 1	Xsec 2	Xsec 3	Xsec 4	Xsec 5	Xsec 6
3,250	0.65	0.68	0.72	0.59	0.67	0.63
3,750	0.70	0.71	0.77	0.64	0.71	0.67
4,250	0.74	0.74	0.81	0.68	0.76	0.72
4,750	0.77	0.76	0.85	0.72	0.79	0.76
5,250	0.81	0.78	0.88	0.75	0.83	0.79
6,000	0.86	0.81	0.93	0.80	0.89	0.85
7,000	0.91	0.85	0.99	0.87	0.95	0.91
8,000	0.97	0.88	1.05	0.93	1.01	0.97
10,000	0.97	0.90	1.07	0.98	1.06	1.04
12,000	0.98	0.92	1.09	1.02	1.10	1.09
14,000	0.99	0.93	1.10	1.05	1.14	1.14
15,000	1.00	0.93	1.11	1.07	1.16	1.16
19,000	0.95	0.89	1.05	1.05	1.17	1.19
23,000	0.92	0.86	1.01	1.04	1.18	1.21
27,000	0.90	0.84	0.98	1.03	1.19	1.23
31,000	0.89	0.83	0.96	1.02	1.20	1.25



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Above Hawes Hole Study Site

TRANSECT 1 — 8,293 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,293	3,250	8,293	31,000
avg	3.83	1.90	3.72	5.75
std dev	1.68	1.14	1.63	2.51
max	7.89	4.39	7.65	11.01
avg diff			0.11	
+/-			-9.72	
max diff			0.24	

TRANSECT 2 — 8,293 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,293	3,250	8,293	31,000
avg	4.42	2.19	3.94	6.11
std dev	2.29	1.51	2.04	2.72
max	10.58	5.79	9.42	13.75
avg diff			0.49	
+/-			-38.81	
max diff			1.16	

TRANSECT 3 — 8,320 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,320	3,250	8,320	31,000
avg	3.80	2.12	4.04	5.81
std dev	1.82	1.24	1.93	3.00
max	8.36	5.19	8.89	13.24
avg diff			0.24	
+/-			20.86	
max diff			0.53	

TRANSECT 4 — 8,320 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,320	3,250	8,320	31,000
avg	3.57	1.69	3.31	5.82
std dev	1.92	1.05	1.85	2.99
max	8.17	4.17	7.72	12.59
avg diff			0.19	
+/-			-17.71	
max diff			0.45	

TRANSECT 5 — 8,320 CFS VELOCITY SET USED

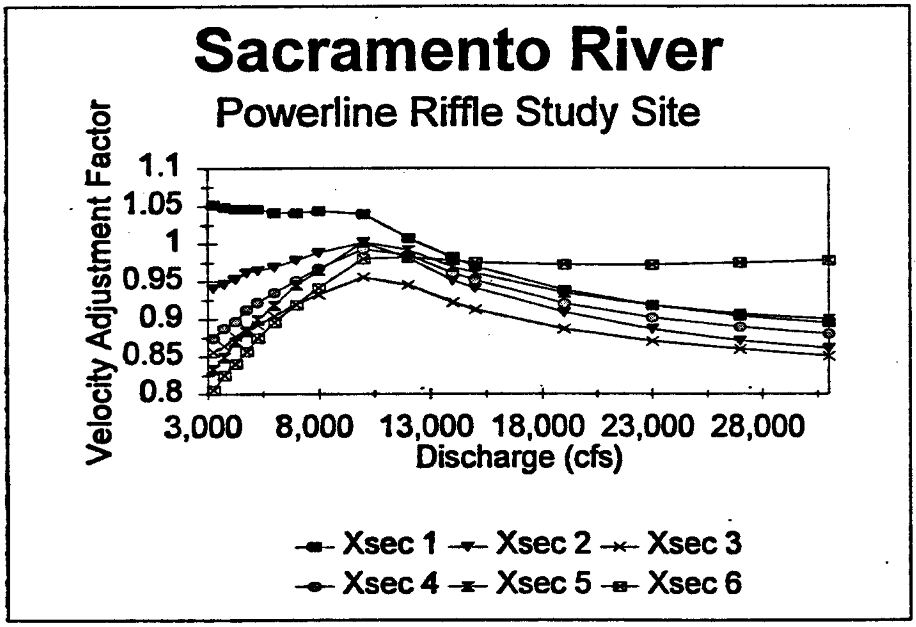
	meas	sim	sim	sim
	8,320	3,250	8,320	31,000
avg	3.31	1.72	3.39	6.07
std dev	1.36	0.85	1.39	2.61
max	5.35	3.07	5.48	9.83
avg diff			0.08	
+/-			6.83	
max diff			0.13	

TRANSECT 6 — 8,320 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,320	3,250	8,320	31,000
avg	3.32	1.73	3.28	6.00
std dev	1.04	0.60	1.02	2.30
max	5.25	2.83	5.18	9.34
avg diff			0.04	
+/-			-4.04	
max diff			0.07	

POWERLINE RIFFLE STUDY SITE

	Velocity Adjustment Factors					
Discharge	Xsec 1	Xsec 2	Xsec 3	Xsec 4	Xsec 5	Xsec 6
3,250	1.05	0.94	0.86	0.87	0.83	0.81
3,750	1.05	0.95	0.86	0.89	0.85	0.83
4,250	1.05	0.95	0.88	0.90	0.87	0.84
4,750	1.05	0.96	0.89	0.91	0.88	0.86
5,250	1.05	0.96	0.89	0.92	0.90	0.88
6,000	1.04	0.97	0.90	0.93	0.92	0.90
7,000	1.04	0.98	0.92	0.95	0.95	0.92
8,000	1.04	0.99	0.93	0.97	0.96	0.94
10,000	1.04	1.00	0.96	0.99	1.00	0.98
12,000	1.01	0.98	0.95	0.99	0.99	0.98
14,000	0.98	0.95	0.92	0.96	0.97	0.98
15,000	0.97	0.94	0.91	0.95	0.96	0.98
19,000	0.94	0.91	0.89	0.92	0.93	0.97
23,000	0.92	0.89	0.87	0.90	0.92	0.97
27,000	0.90	0.87	0.86	0.89	0.91	0.98
31,000	0.90	0.86	0.85	0.88	0.90	0.98



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Powerline Riffle Study Site

TRANSECT 1 — 15,097 CFS VELOCITY SET USED

	meas	sim	sim	sim
	15,097	3,250	15,097	31,000
avg	5.34	2.84	5.18	6.38
std dev	1.68	1.25	1.63	2.38
max	7.73	4.75	7.49	10.02
avg diff			0.16	
+/-			-18.01	
max diff			0.24	

TRANSECT 2 — 15,097 CFS VELOCITY SET USED

	meas	sim	sim	sim
	15,097	3,250	15,097	31,000
avg	5.54	2.60	5.24	6.32
std dev	1.22	1.08	1.14	1.99
max	7.84	4.61	7.40	9.35
avg diff			0.32	
+/-			-36.61	
max diff			0.44	

TRANSECT 3 — 14,628 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,628	3,250	14,628	31,000
avg	5.30	2.29	4.91	6.20
std dev	1.37	0.95	1.27	1.96
max	7.41	4.06	6.86	9.22
avg diff			0.39	
+/-			-54.00	
max diff			0.55	

TRANSECT 4 — 14,628 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,628	3,250	14,628	31,000
avg	5.20	2.50	5.01	6.22
std dev	1.20	0.79	1.15	1.86
max	7.24	3.97	6.98	9.32
avg diff			0.19	
+/-			-26.42	
max diff			0.26	

TRANSECT 5 — 14,628 CFS VELOCITY SET USED

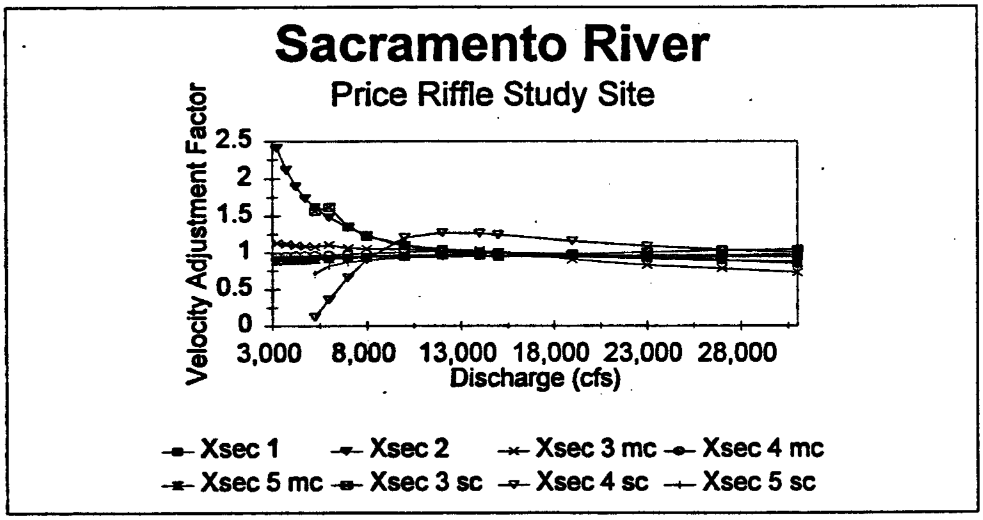
	meas	sim	sim	sim
	14,628	3,250	14,628	31,000
avg	5.05	2.32	4.89	6.17
std dev	1.07	0.71	1.04	1.68
max	6.69	3.56	6.48	8.51
avg diff			0.16	
+/-			-19.85	
max diff			0.21	

TRANSECT 6 — 14,628 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,628	3,250	14,628	31,000
avg	4.52	2.16	4.43	5.67
std dev	1.38	0.64	1.35	2.20
max	5.95	3.02	5.83	7.98
avg diff			0.09	
+/-			-8.68	
max diff			0.13	

PRICE RIFFLE STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2	Xsec 3 mc	Xsec 4 mc	Xsec 5 mc	Xsec 3 sc	Xsec 4 sc	Xsec 5 sc
3,250	0.94	2.41	1.13	0.95	0.90	—	—	—
3,750	0.94	2.12	1.12	0.96	0.90	—	—	—
4,250	0.94	1.90	1.10	0.96	0.90	—	—	—
4,750	0.94	1.74	1.09	0.97	0.91	—	—	—
5,250	0.94	1.62	1.08	0.97	0.91	1.56	0.12	0.71
6,000	0.94	1.48	1.11	0.97	0.92	1.62	0.36	0.82
7,000	0.95	1.34	1.07	0.98	0.93	1.36	0.66	0.87
8,000	0.95	1.23	1.05	0.99	0.94	1.22	0.91	0.90
10,000	0.97	1.10	1.04	1.01	0.96	1.10	1.21	0.93
12,000	0.96	1.05	1.04	1.02	0.97	1.01	1.27	0.94
14,000	0.96	1.01	1.03	1.01	0.99	0.97	1.26	0.95
15,000	0.96	1.00	1.00	1.00	0.99	0.95	1.25	0.95
19,000	0.96	0.95	0.91	0.98	0.98	0.98	1.16	0.94
23,000	0.96	0.92	0.83	0.94	0.94	1.01	1.09	0.94
27,000	0.97	0.89	0.78	0.90	0.90	1.03	1.04	0.94
31,000	0.97	0.88	0.73	0.85	0.85	1.05	1.00	0.95



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Price Riffle Study Site

TRANSECT 1 — 14,371 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,371	3,250	14,371	31,000
avg	5.44	2.97	5.31	6.59
std dev	2.22	1.26	2.14	3.28
max	9.58	5.00	9.33	12.80
avg diff			0.14	
+/-			-12.93	
max diff			0.25	

TRANSECT 2 — 14,371 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,371	3,250	14,371	31,000
avg	5.33	5.73	5.30	6.52
std dev	2.39	2.90	2.40	2.83
max	10.58	12.63	10.55	12.90
avg diff			0.03	
+/-			2.71	
max diff			0.09	

TRANSECT 3 MC — 14,389 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,389	3,250	14,389	31,000
avg	5.63	3.44	5.77	6.40
std dev	1.73	1.57	1.79	1.73
max	10.20	7.60	10.49	10.70
avg diff			0.14	
+/-			11.98	
max diff			0.29	

TRANSECT 3 SC — 14,389 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,389	5,000	14,389	31,000
avg	2.72	0.42	2.60	4.46
std dev	0.87	0.22	0.84	2.51
max	4.30	0.74	4.12	9.66
avg diff			0.12	
+/-			-1.96	
max diff			0.19	

TRANSECT 4 MC — 14,389 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,389	3,250	14,389	31,000
avg	4.93	3.18	4.98	5.85
std dev	1.84	1.51	1.85	2.51
max	8.24	5.69	8.35	11.21
avg diff			0.06	
+/-			5.03	
max diff			0.12	

TRANSECT 4 SC — 8,953 CFS VELOCITY SET USED

	meas	sim	sim	sim
	8,953	5,000	8,953	31,000
avg	1.03	0.04	1.22	3.02
std dev	0.90	0.03	0.86	1.76
max	2.70	0.08	2.92	6.11
avg diff			0.20	
+/-			4.13	
max diff			0.73	

TRANSECT 5 MC — 14,389 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,389	3,250	14,389	31,000
avg	5.09	3.09	4.99	6.32
std dev	1.58	1.34	1.57	1.81
max	7.78	5.53	7.64	8.85
avg diff			0.11	
+/-			-11.72	
max diff			0.36	

TRANSECT 5 SC — 14,389 CFS VELOCITY SET USED

	meas	sim	sim	sim
	14,389	5,000	14,389	31,000
avg	2.72	0.35	2.61	4.67
std dev	1.59	0.17	1.51	2.20
max	4.50	0.61	4.29	6.86
avg diff			0.12	
+/-			-2.41	
max diff			0.21	